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Journal of the Council for Scientific and Industrial Research.

Vol. 16. MAY, 1943. No. 2.

Recent Progress in the Entomological Control of St. John's Wort.

By Frank Wilson and T. G. Campbell.**

Summary.

Three insect enemies of St. John's wort have been established in Australia.

Chrysolina hyperici Forst. is a leaf-eater which was imported from England and, after liberation, disappeared for some years. It re-appeared in large numbers in 1939 at Bright (Victoria), where it has since become increasingly common. It has dispersed along the Oven's valley and German Creek for a distance of eight miles, and occurs in densely populated colonies which rapidly defoliate the host. Repeated defoliation kills the weed which is gradually being thinned out and replaced by grasses. Some small areas have been completely cleared of St. John's wort, and in one paddock, which had long carried a heavy stand of the wort, complete control was effected in a period of two years. By the redistribution of adults, *C. hyperici* has been established in many districts in Victoria and New South Wales. In these recently colonized areas the defoliation of the host becomes increasingly common, causing restricted foliage-growth and seed-production, and a gradually increasing mortality in the host-plants.

The delay in the establishment of *C. hyperici* is attributable to partial infertility in the specimens originally liberated and to the action of predators. The latter still slows down the beetle's rate of increase and renders rather less easy its establishment in fresh areas.

Agrilus hyperici Creutz., a root-boring Buprestid, was introduced from southern France and liberated in 1939 and 1940 in two districts, one in Victoria and the other in New South Wales. The insect has become established at each of the seven sites where liberations were made. The population is increasing rapidly at several of the liberation sites and, in the vicinity of one of them, 50 per cent. of the plants are infested and the infestation is already as heavy as an average infestation in southern France. Some plants have been killed and the growth of others restricted, and, if the increase in numbers is maintained, a considerable effect on the weed should become apparent within two years at this particular liberation site. The rapid increase of this insect is largely due to the freedom of the immature stages from predators.

Chrysolina gemellata Rossi, another leaf-eating insect, was sent from southern France in 1939 and was liberated in this year at Baker's Gully, Bright, where it has become established and has spread for a distance of about a mile. It is not yet sufficiently numerous to have had any great effect on the host-plant, which, however, is somewhat restricted in growth where the *gemellata* are most numerous. As with *C. hyperici*, the adults of *C. gemellata* are preyed upon by scorpion flies, spiders, and probably by birds, and these predators restrict somewhat its rate of increase. Nevertheless, *C. gemellata* has made much more progress during the last three years than did *C. hyperici* during the first three years after its liberation. Recently, *C. gemellata* was liberated at Nullo Mountain, New South Wales, most of the adults utilized having been collected at Baker's Gully.

* An officer of the Division of Economic Entomology.

The retrogression of St. John's wort where *C. hyperici* is numerous, the continuous increase in the numbers of this insect and in the area it occupies, and the ease with which *C. gemellata* and *Agrilus hyperici* have been established, all give ground for some confidence that these insects will later give a useful degree of control of the weed. St. John's wort, in dense stands, occupies a very extensive area, and it will be some years before the insects become so widely distributed and so increased in numbers that they can attain their maximum degree of control over the host-plant.

1. Introduction.

The insects which have been introduced into Australia for the purpose of the control of St. John's wort (*Hypericum perforatum* L.) were obtained from two regions—southern England and southern France. Initially S. Garthside (later assisted by F.W.) began a detailed investigation of the *Hypericum* insects in England, and eventually five species were liberated in Australia: *Chrysolina varians* Schall., *C. hyperici* Forst., *C. brunsvicensis* Grav., *Anaitis efformata* Guen., and *A. plagiata* L. Two papers dealing with this work have been published (Currie and Garthside (1) and Currie and Fyfe (2)). None of these insects appeared to become established, and Currie and Fyfe attributed this to an unfavourable physical environment or, where food and climate appeared suitable, to the action of natural enemies such as ants, bugs, spiders, and birds.

With the hope of achieving success with British insects much reduced, attention was directed to the *Hypericum* insects present in areas of Europe which possess a climate closer to that of south-eastern Australia. The French Riviera seemed as promising a field as any, and a detailed investigation of the insect enemies of St. John's wort present in that area was carried out by F.W. (A Bulletin dealing with the results of this investigation will shortly be published.)

2. Insects Imported from France.

Five insects appeared to be sufficiently promising to justify shipment to Australia. In order of importance they were:

Agrilus hyperici Creutz. (Buprestidae)—a root borer;

Chrysolina gemellata Rossi (Chrysomelidae)—a leaf-eater;

Zeuxidiplosis giardi Kieff. (Cecidomyiidae)—which produces a leaf-bud gall;

Aristotelia morphochroma Wals. (Gelechiidae)—which bores down the stems and eats out the seed-capsules; and

Actinotia hyperici Schiff. (Noctuidae)—a leaf-eater.

It was known from field observations in southern France that, when a high degree of insect control of the weed is achieved at any particular place, *Agrilus hyperici* and *C. gemellata* are the principal instruments of control and that, in the interspecific competition for the reduced food-supply, the other species are more or less eliminated. Consequently, while all five species would eventually have been sent to Australia, it seemed likely that, if *Agrilus* and *C. gemellata* could be established, the introduction of the other three species would be supererogatory. On the other hand, one cannot argue directly from field experience in France to conditions in the field in Australia, because of the extreme complexity of the factors governing population densities in insects, and one of

these factors in Australia—the influence of predators—could conceivably prove so adverse to *C. gemellata* as to reduce greatly its effectiveness here.

During 1939 and 1940, shipments of aestivating adults of *C. gemellata,* of hibernating larvae of *Agrilus hyperici,* and of hibernating pupae of *Actinotia hyperici* were sent from France to Canberra. These arrived in excellent condition. The adults of *C. gemellata* and the pupae of *Actinotia hyperici* were transported by air-mail; the larvae of *Agrilus hyperici,* which were left in the roots of the host-plant, were transported by boat in the vegetable chamber.

By the time that the work in France ceased (June 1940) three attempts to introduce *Zeuxidiplosis giardi* had been made, but none was successful. This is an unusually difficult insect to transport over long distances, since larvae and pupae cannot withstand refrigeration and the adults are shortlived. Once, living plants infested with *Zeuxidiplosis* were shipped in a Wardian cage, but lacking adequate attention on the boat, the plants and insects died. Full-grown larvae and pupae sent (on two occasions) by air, failed to arrive in Canberra before the adults had emerged and died.

No attempt had been made to ship *A. morphochroma* by the time that the European work closed down, for difficulty in breeding had retarded progress with this insect. Actually, there is no reason to think that successful shipment would be difficult, and the hibernating larvae could probably be transported quite satisfactorily by boat in cold storage.

Consequently, of the five species which were considered to be worth shipping to Australia, the most important two species (*Agrilus hyperici* and *C. gemellata*) and the least important (*Actinotia hyperici*) arrived in Canberra.

Actinotia has not, however, been liberated and the cultures of this insect maintained at Canberra have been destroyed. There were two reasons for this. First, it was considered unlikely to be nearly as effective in the field as the other species, because it would be highly susceptible to predator attack and has not a particularly high reproductive rate to counterbalance this. More important, being a leaf-eating Noctuid, the risk of it attacking alternative hosts is greater than in the other major *Hypericum* insects, and the fact that its close relative, *A. polyodon,* has been recorded from *Astralagus, Acer,* and *Prunus domesticus,* besides *Hypericum,* made this risk greater than was considered permissible, despite the fact that in starvation tests it had shown no disposition to attack other plants.

This left *Agrilus hyperici* and *Chrysolina gemellata* available for liberation in Australia, and any attempts to introduce *Z. giardi* or *A. morphochroma* will have to await the end of the war.

3. Insects Established in Australia.

(i) *Chrysolina hyperici* Forst.

Since the publication of Currie and Fyfe's paper (2), *Chrysolina hyperici* has reappeared in large numbers in the vicinity of Oake's Bridge, Bright (Victoria) where 1,340 adults had been liberated in November, 1934, and the colony had disappeared by June, 1935 (Currie

and Fyfe). On 25th November, 1939, it was found (by T.G.C.) in large numbers feeding on the weed and, from the damage caused to the host-plant, it was concluded that the insect had been present in fairly large numbers in the preceding year. Since that time the population has increased considerably and adults have been collected there in November or early December of each year and liberated in other districts. In 1939, about 6,500 adults were collected and liberated elsewhere (by Mr. A. L. Tonnoir and T.G.C.). In 1940, we obtained approximately 52,000 for redistribution, whilst in 1941 90,000 adults were collected (by T.G.C.) for liberation in other localities.

The following list gives details of the liberations made:—

Date liberated.	Approx. No. of Adults.	Liberation Site.	Remarks.
7.12.39	500	Baker's Gully, Bright, Vict.	Present in small numbers.
7.12.39	500	Rifle Range, Bright	Numbers dwindled; has disappeared.
7.12.39	500	German Creek, Bright	Now very numerous.
7.12.39	500	Salt Trough Creek, Tawonga Gap, Vict.	Present in small numbers.
16.12.39	1,000	Mannus Hill, Tumbarumba, N.S.W., No. 1	Not recovered.
16.12.39	1,000	Mannus Hill, Tumbarumba, N.S.W., No. 2	Persists in small numbers.
16.12.39	1,500	Mannus Hill, Tumbarumba, N.S.W., No. 3	Persists in small numbers.
16.12.39	1,000	Near Tumbarumba	Apparently died out.
22.11.40	7,000	Waterford–Crooked River-road, Dargo, Victoria, No. 1	Adults numerous (Nov., 1941).
22.11.40	7,000	Waterford–Crooked River-road, Dargo, Victoria, No. 2	Adults present (Nov., 1941).
22.11.40	6,000	Waterford–Crooked River-road, Dargo, Victoria, No. 3	Adults present (Nov., 1941).
8.12.40	5,000	Harrietville, Vict.	Now very numerous.
10.12.40	5,000	Tawonga, Vict.	Now numerous.
8.12.40	4,000	Happy Valley, Myrtleford, Victoria	Now very numerous.
29.11.40	8,000	Catchment area, Mudgee, N.S.W.	Present in moderate numbers.
30.11.40	10,000	Piambong, Mudgee	Now numerous.
26.11.41	25,000	Waterford–Crooked River-road, Dargo, Victoria, No. 4	Not yet revisited.
26.11.41	12,500	Waterford–Crooked River-road, Dargo, Victoria, No. 5	Not yet revisited.
26.11.41	12,500	Waterford–Crooked River-road, Dargo, Victoria, No. 6	Not yet revisited.
3.12.41	10,000	Springside, Orange, N.S.W.	Now numerous.
3.12.41	5,000	Sodwalls, N.S.W., No. 1	Present in moderate numbers.
3.12.41	5,000	Sodwalls, N.S.W., No. 2	Present in fair numbers.
3.12.41	10,000	"Klovera," Sodwalls	Moderately numerous.
4.12.41	10,000	Lugan Park, Nullo Mtn., N.S.W.	Present in good numbers.

Of the 24 liberation sites, 21 have been revisited and at 18 of these, at least, the colonies continue to develop. In the first 8 liberations, where the maximum number of adults freed was 1,500, at only one site has *C. hyperici* become sufficiently numerous to consider it well established. In all the other 13 liberation sites revisited, where 4,000 to 10,000 adults were used, the progress towards establishment of the insect is considered to be very satisfactory.

The great delay in the establishment of this insect—for it reappeared four years after its apparent extermination—is of considerable interest. Currie and Fyfe (2) have written of the exceptional difficulties experienced in breeding this insect in the laboratory: imported adults or adults reared from imported eggs laid very few eggs and these were seldom fertile. The reason for this is unknown, but it seems likely that infertility in the insects liberated in the field greatly reduced their reproductive rate.

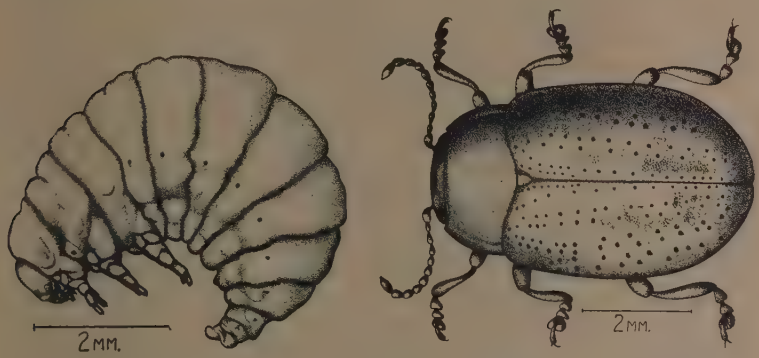

FIG. 1.—Fully developed larva (left) and adult (right) of *Chrysolina hyperici* (leaf-eating Chrysomelid bettle).

Apart from this special difficulty, there are several inherent, adverse factors which militate against successful establishment when insects are liberated in a new country. These include the natural dispersal of the insects which tends to result in the isolation of numerous individuals, thereby causing a reduction in the reproductive rate, and the action of native predators or parasites, which further reduces the density of the liberated insects and, consequently, their effective rate of reproduction. There is considerable evidence that this factor has usually had an overwhelming effect on introduced *Hypericum* insects. Also, the life-history of an insect from the northern hemisphere must be adjusted to the difference in time of the seasons in the southern hemisphere. This may be a relatively simple matter in insects having a hibernating stage which can be artificially prolonged for six months in a refrigeration chamber, but in the absence of such a stage, the adjustment may be difficult to induce.

(ii) *Chrysolina gemellata* Rossi.

This insect, which oviposits from autumn to spring and aestivates in summer, was liberated in August and October 1939, the adults employed being aestivating specimens sent by air from France in July.

These beetles, therefore, not only had to adjust themselves to winter temperatures, but also to leave the aestivating state, feed for several weeks, mate and oviposit: all this, when the oviposition season was already very advanced at the time of liberation. Despite this, the insect has become established.

The details of the liberations of the imported adults (made by T.G.C. and Mr. G. R. Wearne) are as follows:—

Date liberated.	Approx. No. of Adults.	Liberation Site.	Remarks.
11.8.39	2,000	¾ mile N.E. of Bright, Vict.	None recovered.
11.10.39	400		
11.8.39	2,000	Baker's Gully, Bright, No. 1	Well established.
10.10.39	1,000	Baker's Gully, Bright, No. 2	

It was not until late in October, 1942, that this insect was recovered. Earlier examinations of the liberation sites suggested that it had rapidly died out, but the insects were eventually recovered in Baker's Gully some distance from the two points where liberations had been made. By early December, 1942, sufficient adults had emerged to make it possible to collect some 4,000 adults in one day from a paddock in which the insects were particularly numerous, and these adults, together with 1,700 adults from the cultures maintained at Canberra, were liberated on 5th December at a site on the top of Nullo Mountain, New South Wales. Among the 4,000 adults collected at Baker's Gully was a very small proportion of *C. hyperici*, so this insect too has been liberated in small numbers at this site.

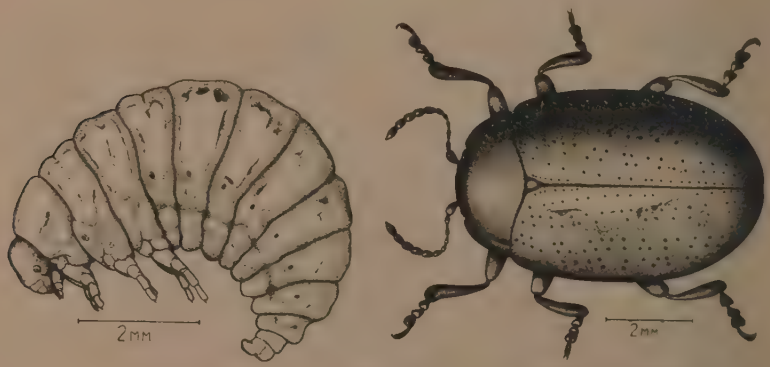

FIG. 2.—Larva (left) and adult (right) of *Chrysolina gemellata*.

C. gemellata has spread for about a mile along Baker's Gully and, while it is not yet very numerous, it may already be regarded as firmly established.

(iii) *Agrilus hyperici* Cr.

Agrilus hyperici has been liberated at four sites near Bright (Victoria) and at three sites near Mudgee (New South Wales). At every place recoveries have been made and the insect may now be regarded as established. The details of the liberations are:—

Date liberated.	Approx. No. of Adults.	Liberation Site.	Remarks.
3.11.39	142	Baker's Gully, Bright, No. 1	Occurs in moderate numbers.
24.11.39	300	Baker's Gully, Bright, No. 2	Occurs in moderate numbers.
24.11.39	300	Baker's Gully, Bright, No. 3	Moderately common.
20.11.40	1,050	Baker's Gully, Bright, No. 4	Very numerous.
11.9.40	1,500	Catchment area, Mudgee	Quite numerous.
30.10.40	800		
10.9.40	1,030	"Yamba," Piambong, Mudgee, No. 1	Common.
2.10.40	478	"Yamba," Piambong, Mudgee, No. 2	Present in fair numbers.
30.10.40	1,017		

The first liberation was made by Mr. A. L. Tonnoir. Except for the liberation at No. 4 site, Bright (made by F.W. and T.G.C.), all others were made by T.G.C. All the adults employed in these liberations emerged in the insectaries at Canberra from infested roots sent from France in 1939 and 1940.

Apart from these adult liberations, oviposition was secured on several hundred plants near the Baker's Gully No. 4 site, in December and January, 1941, by "sleeving" pairs of adults on successive plants every day. At the present time about 50 per cent. of the plants are infested in the dense stand of St. John's wort between and about this "oviposition plot" and the No. 4 liberation site. As many as four larvae were found in a single root and, over an area about 50 yards square, the infestation was quite as heavy as an average infestation in southern France. Infested roots were located with fair ease as far as 80 yards from the liberation site, and the population increase in this vicinity (after two generations) has been very great.

By comparison with the No. 4 site, the three liberation sites chosen in the previous year in the same valley have been relatively unproductive—despite an extra generation in the field. The insects are increasing—more particularly at the No. 3 site—but relatively slowly. There are several reasons for this. First, No. 4 is on the northern slope of the valley and the other three are on the southern slope, and it is known that high temperatures and maximum sunlight greatly favour a high rate of reproduction in this insect. Secondly, the small number of adults liberated at each site in 1939 and their dispersal after liberation probably greatly reduced the rate of reproduction, for the females have to be fertilized every day or two, and in the absence of a sufficient concentration of adults the reproductive rate falls considerably.

The progress of the three colonies at Mudgee is very satisfactory, though not so rapid as that of the No. 4 site at Bright. At the Piambong No. 1 site, roughly 30 per cent. of the plants near the point of liberation are infested, while at the No. 2 site the level of infestation is about 7

per cent., and at the catchment area about 5 per cent. Although the areas involved are small, the St. John's wort occurs in dense stands and the *Agrilus* population, relative to the numbers liberated, is considerable.

FIG. 3.—Larva (left) and adult (right) of the root-boring Buprestid, *Agrilus hyperici*.

4. Present Effect of Insects Established.

(i) *Chrysolina hyperici* Forst.

In the three years since its reappearance, *C. hyperici* has spread naturally for at least eight miles from the original establishment site at Oake's Bridge, Bright. The dispersal has been chiefly in an easterly direction in the dense stands of *Hypericum* in the Oven's Valley and along German Creek. The insect is extremely common in this area and has achieved a greater population density than it does in England or France. The beetles do not occur in all the stands of St. John's wort present in the eight miles of country which they have traversed, and there is no doubt that they are dispersing by flight. This is interesting, because during several years' work with the insect in England flight was never observed in the field, though occasionally adults subjected to fairly high temperatures in the laboratory took to wing. (We have seen *C. hyperici* in flight at Mudgee, New South Wales).

The increase in the *C. hyperici* population and the area it occupies in the Bright district has been considerable during 1942, and with increasing frequency it is being discovered in fresh localities. The rate of its numerical and territorial expansion is accelerating, and this is expected to continue for several years even in the Bright district.

Wherever *C. hyperici* is numerous, complete defoliation of the host by the larvae and adults is a common feature. The subsequent growth of the plants is much restricted and few flowering stems are produced, these giving rise to very few flowers which often fail to produce seed. In this way the weed is becoming considerably thinned out and is being replaced by grasses. Where the plants are repeatedly defoliated they die. This may be observed at many places near Bright. Characteristically, a colony develops at one spot and defoliates the weed in a clearly defined circle of, say, 50 yards diameter. Outside this area there remains a thick stand of *Hypericum* practically unaffected by the insects. In the next season, the regrowth and seedling plants on the cleared area are eaten, and the beetles attack the plants on the fringe, until, by the end of season, the diameter of the cleared area is increased to, say, 150 yards. In this way the insects are continually working out from the cleared ground attacking the gradually lengthening circular wall of St. John's wort while preventing regrowth on the cleared land.

The progress by this méthod may be quite rapid. For example, in one field (Mr. Cherry's paddock) a few score adults of *C. hyperici* were located in December, 1940. This field, which is about three acres in size, had carried a heavy stand of St. John's wort for many years. A year later, the insects had completely defoliated and largely killed the weed within a circle of about 100 yards diameter. By December, 1942, all the St. John's wort had been completely defoliated by the larvae and most of it killed, and the emerging adults had been compelled to migrate elsewhere for food. There will, no doubt, be some regrowth and seedlings later, but this will be controlled by the immigration of adults from colonies adjacent to the paddock.

Such visible evidence of the effectiveness of *C. hyperici* in controlling St. John's wort is becoming increasingly common as the population of the insect grows rapidly in the Ovens Valley and along German Creek. It is reported that farmers are becoming aware of the value of the insect and are collecting adults and liberating them in their infested fields. In this way the dispersal of the insect throughout areas suffering from the noxious weed will be hastened.

It has been observed that *C. hyperici* travels chiefly along the valleys and shows little tendency to disperse uphill. This will probably result in the insects having little effect on the weed on the hill-slopes until a high degree of control has been obtained in the valleys and the insects are compelled by food-shortage to migrate uphill.

It is clear that the progress of *C. hyperici* in the vicinity of Bright since 1939 has been remarkable, and that during the past year effective control of the weed has been obtained at several places. However, the dense stands of St. John's wort extend for miles in valleys and on hill-sides in this part of Victoria, and it will be some years before the insect becomes generally distributed throughout the wort country.

Where *C. hyperici* has been established in other districts by the liberation of adults collected at Bright, there has, naturally, not yet been a sufficient build-up of the population to achieve results comparable with those at Bright. Nevertheless at some of the earlier redistribution sites where larger numbers of *C. hyperici* were liberated (as at Harrietville, Happy Valley, Dargo, and elsewhere) defoliation of the host occurs, and some plants have been killed whilst others produce few flowers which yield little seed. In such places the weed near the liberation site has already been thinned out considerably.

(ii) *Chrysolina gemellata* Rossi.

A recent survey has shown that this insect is well established over a distance of one mile in Baker's Gully, Bright. Colonies occur here and there in the dense stands of St. John's wort, and in one field there was a fairly heavy concentration of adults. Here some effect on the host plant was evident, but generally the St. John's wort has not yet been appreciably affected by this insect. Nevertheless, given the unfavourable circumstances of the liberations (mentioned above), it is remarkable that in three generations the insect has covered so wide an area.

It was observed that the adults took to wing readily, and this accounts for the wide dispersal of the relatively small population in Baker's Gully. As with *C. hyperici*, *gemellata* was not observed to fly in Europe except when submitted to high temperatures in the laboratory.

(iii) *Agrilus hyperici* Creutz.

Since *Agrilus hyperici* is univoltine and the liberations were made as recently as 1939 and 1940, there has naturally been too little time for a population build-up sufficient to produce a marked effect on the weed in those localities where the insect is established. However, plants can readily be found which have been killed by this Buprestid, and it is a perfectly safe assumption (from our knowledge of this insect in France) that, where plants are infested by this insect but not killed, their growth is considerably restricted.

5. Prospects of Effective Control.

Although *Chrysolina hyperici* has now been established in many localities, the fraction of the total area covered by St. John's wort in Australia which has been occupied by this insect is very small. The fraction occupied by *Agrilus* and by *Chrysolina gemellata* is still smaller. The present limited distribution of these insects is natural since they have only been established for a relatively brief period. Already *C. hyperici* and *Agrilus* have been established in some of the warmest and some of the coolest of the Australian *Hypericum* areas, and there is no reason to doubt that the field populations will increase for a long while to come and that, aided by human redistribution of the adults for some years, both insects will eventually occur in most or all of the St. John's wort areas. *C. gemellata* at present is only established in one of the cooler districts, though it has also been liberated recently in New South Wales. It is, however, quite certain that the higher temperatures of the more northern *Hypericum* districts will not prevent the establishment there of *gemellata*, for it flourishes in southern Europe where very high summer temperatures occur. Indeed, it is likely, judging from the distribution of *C. gemellata* and *C. hyperici* in France, that the former will be more successful than the latter in the warmer districts.

Assuming that these insects do become established throughout the *Hypericum* country, what is the prospect of them effecting a reasonably high degree of control? To attempt an answer to this question the insects must be considered separately.

Agrilus hyperici has been established with the greatest ease in Australia and, apart from the fact that the climate is suitable, this is largely attributable to the inaccessibility of the immature stages (hidden in the roots of the host) to predators or parasites. This freedom from enemies is an important factor which, despite the low reproductive rate of *Agrilus* (as compared with the *Chrysolina* spp.) will probably permit the root-borer population to develop rapidly. Although the damage caused to the weed at Baker's Gully is still slight, the increase in population in the last two years has been such that, if the same rate is maintained for two more years, a considerable effect on the host-plant will become apparent.

From the study of *Agrilus* carried out in France, it is known that at times this insect practically eliminates areas of St. John's wort. In the absence here of its specific parasite, *Dinarmus* n.sp. (Pteromalidae), there is no apparent reason why *Agrilus* should not more rapidly increase in population than it does in southern France, and be correspondingly more effective in the control of the weed.

With *C. hyperici,* the situation is different. The action of predators restricts this insect's rate of increase where it is established, and makes it less easy to establish at new sites. On the other hand, *hyperici* is free in Australia from a number of parasites which attack it in Europe, and its high reproductive rate (several thousand eggs per female) permits it to multiply despite the predators, if sufficiently large numbers are liberated initially. From observations made in the field in Australia, it is known that a useful degree of control is already being exercised and that the level of control is rising with the increase in the *C. hyperici* population. Where these observations have been made, there is no apparent reason why the process should not continue until the reduction in the host-plant causes a reduction in the insect population. The probability is that *hyperici* can be established in all the cooler areas at least, and that in these districts the insect will be as effective in controlling the host as it is at Bright. On the other hand, in warmer areas the result may not be so satisfactory, for *C. hyperici* is less tolerant of high temperatures than is *C. gemellata.*

The ease with which *C. gemellata* has become established and has spread in Baker's Gully is most promising for the future of this insect. It has made as much progress in its first three years as *C. hyperici* achieved in the five years after its liberation in 1934. From this it would seem that *gemellata* will be as valuable as *hyperici* even in the cooler areas, while in warmer districts it is almost certain to be more effective. As with *C. hyperici, gemellata* is subjected to attack by predators. Scorpion flies and spiders have been observed to attack the adults, and birds are very probably predaceous on them; doubtless the ubiquitous ant takes toll of the larvae. It is likely, however, that these predators are incapable of preventing the continued increase in the beetle's numbers, for it seems probable that polyphagous predators do far more harm, relatively, when the numbers of the host are low than when it is well established and numerous.

C. gemellata is very common in southern France, where the density of its population and the damage caused to the host is similar to that now observable at Bright with *C. hyperici.* In the absence of its parasites in Australia, *gemellata* should rapidly increase in numbers and it should be even more effective than it is in France. It seems probable that this insect will prove at least as valuable as *C. hyperici,* and that it will prosper in the warmer districts which may be less suitable for *C. hyperici* than the region around Bright.

Assuming that all three established insects become widespread and numerous, they may eventually compete for an inadequate food supply, and under these circumstances it is probable that the Chrysomelids will succumb. This effect was observed in France when a high degree of insect control of the host-plant occurred. The dominance of *Agrilus* in interspecific competition is due to the fact that the root-system is the last part of the plant to die and, consequently, the *Agrilus* larvae can often develop when no foliage is present for the leaf-eating species.

In the event, therefore, of a high degree of control of the host, it seems quite possible that *Agrilus* will be the predominant insect, and that the *Chrysolina* species will play a subsidiary role.

6. Acknowledgments.

In the selection of suitable liberation sites and in making observations on the progress of insect colonies, we have received help from many quarters, especially from departmental and local Government officers in Victoria and New South Wales. We are particularly indebted to Mr. E. J. Pemberton, Chief Inspector of the Vermin and Noxious Weeds Branch of the Department of Lands and Survey of Victoria, and to Messrs. M. Coleman and J. C. Reeve, inspectors for the Bright and Dargo districts respectively. Acknowledgment of assistance is also due to Messrs. K. G. Carn, A. Pearson, S. C. Hodgson, and G. Nicholson, of the New South Wales Department of Agriculture; to Messrs. C. James and J. Walsh, of the Cudgegong Shire Council; and to Mr. J. C. Brinsmead, of Tumbarumba.

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Our thanks are also due to Dr. A. J. Nicholson for advice during the course of the work and for several suggestions made after reading the original manuscript of this article, and to Mrs. E. Rankin for the illustrations of the adults and larvae of the established insects.

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The Care and Use of Slip Gauges.

By N. A. Esserman, B.Sc., F.Inst.P., and E. E. Adderley, B.Sc.†*

1. Introduction.

In this country and in England,‡ the term "Slip Gauge" refers to a rectangular block of hardened steel with two faces lapped flat and parallel to an accuracy of a few millionths of an inch, and the distance between these two surfaces, called the length, is correct to the same order of accuracy. (The requirements for slip gauges are given in detail in British Standard Specification No. 888-1940 for "Slip (or Block) Gauges and their Accessories.")

The surfaces of these gauges will wring together if slid over one another. The thickness of any film existing between the two surfaces is small enough to be neglected.

The conditions necessary for wringing to take place are—

(1) The surfaces should be flat to within 0″·000 010 or less.

(2) Surface finish should be of high quality.

(3) No raised metal or burrs should occur on the surfaces.

Slip gauges are marketed in sets of various sizes. The largest in common use contains 81 pieces, of the following sizes:—

in.	in.	in.	in.
0·100 1	0·113	0·133	0·2
0·100 2	0·114	0·134	0·25
0·100 3	0·115	0·135	0·3
0·100 4	0·116	0·136	0·35
0·100 5	0·117	0·137	0·4
0·100 6	0·118	0·138	0·45
0·100 7	0·119	0·139	0·5
0·100 8	0·120	0·140	0·55
0·100 9	0·121	0·141	0·6
0·101	0·122	0·142	0·65
0·102	0·123	0·143	0·7
0·103	0·124	0·144	0·75
0·104	0·125	0·145	0·8
0·105	0·126	0·146	0·85
0·106	0·127	0·147	0·9
0·107	0·128	0·148	0·95
0·108	0·129	0·149	1
0·109	0·130	0·05	2
0·110	0·131	0·1	3
0·111	0·132	0·15	4
0·112			

A handy, less costly set consists of 41 pieces, of the following sizes:—

in.	in.	in.	in.
0·05	0·102	0·13	0·4
0·100 1	0·103	0·14	0·5
0·100 2	0·104	0·15	0·6
0·100 3	0·105	0·16	0·7
0·100 4	0·106	0·17	0·8
0·100 5	0·107	0·18	0·9
0·100 6	0·108	0·19	1
0·100 7	0·109	0·1	2
0·100 8	0·11	0·2	3
0·100 9	0·12	0·3	4
0·101			

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† An officer of the National Standards Laboratory, Sydney.

‡ In America, the term "Slip Gauge" refers to a flat, double-ended Go, No Go gauge; the term "Block Gauge" is used to denote what we call Slip Gauges.

A set of 49 pieces contains the same slips as the 41-piece set, with the following additions:—

in.	in.
0·01	0·06
0·02	0·07
0·03	0·08
0·04	0·09

Fig. 1 shows such a 49-piece set with two additional "protective" slip gauges.

Fig. 1.—A 49-piece set of EL slip gauges, with two "protective" slip gauges.

Several special purpose sets are also on the market, the most important of which, shown in Fig. 2, is a set of two 0″·1 slips made from specially hard steel. These are used on the ends of combinations

Fig. 2.—A set of EL "protective" slip gauges.

to minimize the wear on the slips from the other sets, and are known as "protective" slip gauges. It is of the utmost importance that these "protective" slip gauges be used with the marked surfaces on the outside of a combination.

2. Making up a Combination.

From the above sets, any nominal dimension from 0″·3 to 12″ in steps of 0″·000 1 may be built conveniently. For example, suppose the length 0″·820 2 is required. This may be built up from the 41-piece set with two protective slips as follows:—

in.	
0·1	protective slip
0·100 2	
0·15	
0·17	
0·2	
0·1	protective slip
0·820 2	

Each set should be provided with a table of errors, giving the departure from nominal size of each slip. The following is a table of errors of one particular 41-piece set:—

MEAN ERRORS FROM NOMINAL SIZE AT 68°F.
UNIT = 0·000 010 INCH.

Nominal Size.	Mean Error.	Nominal Size.	Mean Error.
in.		in.	
0·05	+ 1·5		
0·100 1	+ 0·5	0·11	+ 0·5
0·100 2	+ 1·0	0·12	0·0
0·100 3	+ 0·5	0·13	+ 1·0
0·100 4	+ 1·5	0·14	+ 2·0
0·100 5	+ 1·5	0·15	− 0·5
0·100 6	+ 1·0	0·16	+ 1·0
0·100 7	+ 0·5	0·17	− 0·5
0·100 8	+ 2·0	0·18	+ 1·0
0·100 9	0·0	0·19	+ 0·5
0·101	0·0	0·1	+ 1·0
0·102	+ 2·5	0·2	+ 1·0
0·103	+ 1·5	0·3	+ 1·5
0·104	+ 1·0	0·4	0·0
0·105	+ 1·0	0·5	+ 2·0
0·106	+ 0·5	0·6	+ 0·5
0·107	+ 1·5	0·7	+ 1·5
0·108	+ 0·5	0·8	+ 0·5
0·109	+ 1·5	0·9	0·0
0·1 PS	+ 1·0	1	− 0·5
0·1 PS′	+ 2·0	2	+ 2·0
		3	0·0
		4	0·0

A plus sign (+) indicates that the gauge is above nominal size, and a minus sign (−) indicates that the gauge is below nominal size.

Example.—The actual mean size of the 0·05 inch gauge is 0·050 015 inch.

Using these errors, the above combination would be built up as follows:—

Nominal Size.	Errors.	
in.	in.	
	+	—
0·1	0·000 010	
0·100 2	0·000 010	
0·15		0·000 005
0·17		0·000 005
0·2	0·000 010	
0·1	0·000 020	
0·820 2	0·000 050	0·000 010
+ 0·000 040	— 0·000 010	
0·820 240	0·000 040	

The actual size of the combination, therefore, is 0″·820 240.

For work in which an accuracy of 0″·000 1 is sufficient the gauges could be used without consideration of errors, but for work of greater accuracy, the errors would have to be applied.

3. Accessories.

A number of makers of slip gauges supply accessory equipment adding to the ease and certainty with which the gauges can be used for various purposes. Fig. 3 illustrates one such set. Included in the set are internal measuring jaws, external measuring jaws, centre point, scriber, height gauge base, toolmaker's straight edge, and slip gauge holders.

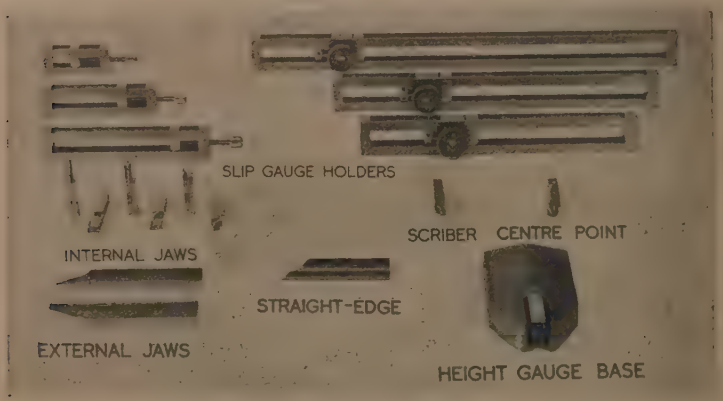


Fig. 3.—Slip gauge accessories.

The internal measuring jaws can be used in pairs to check dimensions of holes by wringing the jaws to either end of a combination of slip gauges in order to make up the required dimension. It is to be noted that in such use the contact of the measuring face with the hole is along a line, and wear will readily take place. It is essential that

where such accessories are frequently used the dimension between the cylindrical and the flat surfaces should be checked regularly.

In the use of accessories which project beyond the slip gauges, holders can, with great advantage, be used, as in Fig. 4, to receive the complete combination. They perform a useful means of holding the unit and prevent accidental breaking of joints.

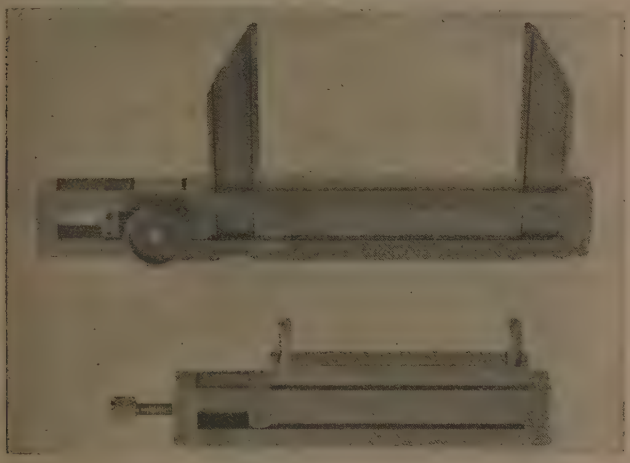


Fig. 4.—Slip gauges and jaws in holders.

While a combination of slip gauges can be used directly on a surface plate in the determination of a height, it can readily be understood that the comparatively narrow cross-section of the slip gauges renders such a pile relatively unstable. Fig. 5 shows how advantage

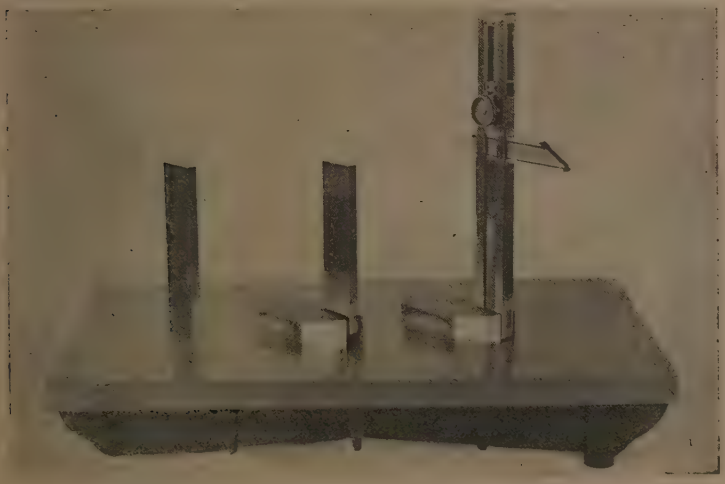


Fig 5.—Use of slip gauges with base and holder.

should be taken of the base to which the gauges can be wrung to form a more stable block. In addition, should a projecting accessory be used, holders can be employed in conjunction with the base.

In using holders care should be taken to ensure that in no case does the locking screw bear directly against a slip gauge. Certain small size holders are supplied without locking pads. Holders should be carefully inspected and brass locking pads made for holders where pads are missing.

4. Care of Gauges.

Because the wringing property of gauges depends upon their surface finish and flatness, they should never be used in any manner which would impair the finish and flatness. All surfaces coming into contact with the slip gauges should be grit-free, especially hard metal surfaces. A small piece of grit remaining on the surface of a slip gauge and rubbed against another gauge will raise a burr on both slips. This burr will prevent wringing and may burr other gauges. One small piece of grit in this manner can burr a whole set of gauges.

Slip gauges should never be used for the routine checking of gauges. The use of check gauges and comparators is strongly recommended. The cost of check gauges will not be as great as the replacement cost of a set of slip gauges. Once a slip gauge becomes worn and the surfaces depart from flatness and parallelism, it is useless, and in most cases it is impossible to recondition it. Any standard becomes useless if worn or mutilated—a condition to which slip gauges can easily be reduced by careless handling. Slip gauges are the fundamental length reference in the tool-room, and should be given the care and respect of all standards.

As a check on the misuse of slip gauges, wherever possible one person *only* should be responsible for the care of the set, wringing and unwringing combinations, detection and removal of burrs, and cleaning of the gauges.

5. Cleaning and Prevention of Corrosion.

Slip gauges are stored in their boxes with a protective coating of pure yellow vaseline or other suitable rust preventer, and when not in use they should be returned to the same condition. This protective coating is best removed with a solvent and not just wiped off.

A piece of clean, soft cloth soaked in benzoline can be used to remove the coating. A more satisfactory method, although more elaborate, is the complete removal of the protective coating in a bath of white spirit. A suggested lay-out for such a procedure is illustrated in Fig. 6.

The Winchester bottle is used as a reservoir for the white spirit (not benzoline), which is siphoned off into the cloth-lined tray beneath. The gauges are placed in this tray and afterwards lifted out, wiped with a clean, dry piece of cloth and transferred to the slip gauge tray described later.

After use, the gauges should be thoroughly wiped and again coated with a rust preventer before being returned to the box, as in Fig. 7. A piece of chamois with a liberal supply of the grease on one side can be used for this purpose.

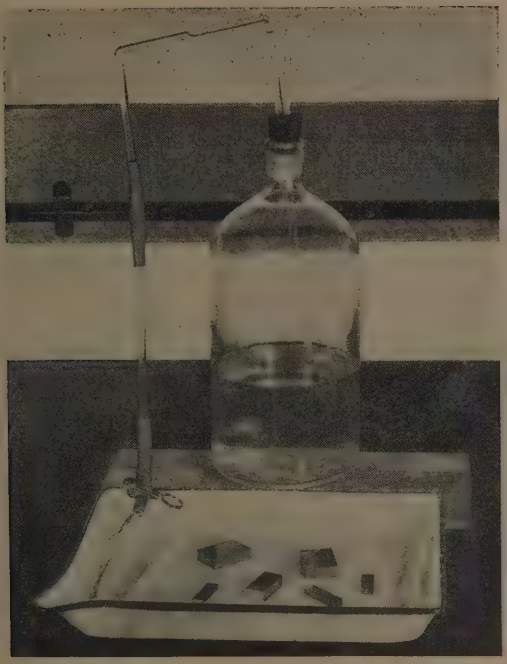


FIG. 6.—Cleaning apparatus for removing protective grease from slip gauges.

The thorough wiping of the gauges before greasing cannot be too strongly stressed. Greasing is of no use whatsoever if finger-prints are not previously removed. Grease covered finger-prints are capable of corroding gauges.

The care of slip gauge surfaces is extremely important. If the above cleaning and care of gauges seem time-consuming, it should be remembered that a slip gauge becomes totally unuseable if damaged, and longer hold-ups in production will occur.

FIG. 7.—Returning slip gauges to box. Greasing of slip gauge (left); Placing in box (right).

6. Detection of Burrs.

As a routine matter, slip gauge surfaces should be frequently tested for burrs. Burrs may be detected in one of two ways. The first method, while not as accurate as the second, is more rapid and requires less skill. A small toolmakers' straight-edge is held lightly between the forefinger and thumb and passed along the clean surfaces of the gauge, as shown in Fig. 8, the only pressure applied being that supplied by the weight of the straight-edge. The presence of a burr is felt by a small bump of the straight-edge, and, in the case of large burrs, a definite "clink" is heard. By moving the straight-edge backwards and forwards over the suspected spot, the location of the burr is easily detected.

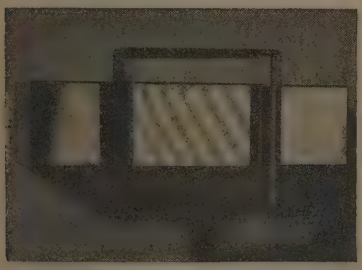
Fig. 8.—Testing for burrs with a straight-edge.

The second method depends upon the formation of optical interference bands between the slip gauge surface and the surface of a glass optical flat. A flat sufficiently accurate for this test consists of a piece of selected plate glass, $\frac{1}{4}''$ x $\frac{3}{8}''$ x $\frac{5}{8}''$, with ground edges and free from scratches. If both slip and glass surfaces are well cleaned and dry, coloured bands will appear when the two surfaces are brought into contact. By holding the glass slip along the front edge and moving it along the gauge surfaces, as in Fig. 9, the presence of even the most minute burr is indicated by a sudden jump of the coloured bands. It is important that the direction of the bands be at right angles to the direction of movement of the glass, as in Figs. 10 and 12. Some little practice will

Fig. 9 (left).—Holding the test glass.

Fig. 10 (right).—Position of interference bands while moving the glass across the surface.

be necessary to obtain the fringes running in the right direction, and more practice will be necessary to distinguish between the jump of the bands, as in Fig. 11, caused by a burr and their movement due to unsteadiness of the hand. By going backwards and forwards over the suspected area, the constant jump of the bands caused by a burr can be distinguished from the inconstant wobbling caused by the hand.



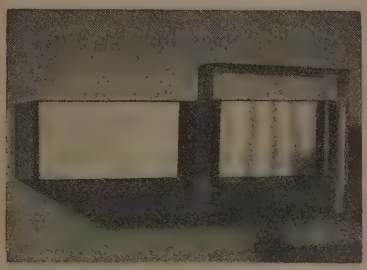


Fig. 11 (left).—Movement of bands caused by a burr.
Fig. 12 (right).—Return of bands to normal position after passing a burr.

A scratch on a piece of glass is usually surrounded by high glass, and, if moved across a slip gauge surface, will burr it.

Pieces of glass suitable for burr testing may be obtained for a nominal charge on application to the Officer-in-Charge, National Standards Laboratory, Chippendale, N.S.W.

7. Removal of Burrs.

Burrs, once detected, should be removed as soon as possible and the slip gauge put to one side and not used until the burr is removed. Burrs on the edges of the wringing face may be removed in the tool-room with a piece of fine Arkansas Stone. The stone is moved across the edge away from the surface, as in Fig. 13. Further testing with the straight-edge or glass will indicate when the burr has been removed.

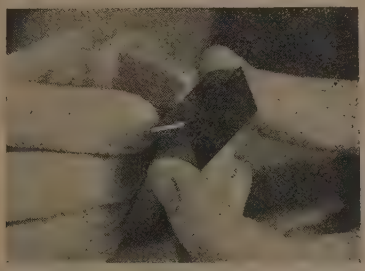


Fig. 13.—Removal of edge burr by moving a piece of Arkansas Stone across the edge away from the surface. Commencement of stroke (left). End of stroke (right).

Burr removal should not be done in the vicinity of other slips or places where slips are handled. Small pieces of abrasive have a habit of clinging to slip gauge surfaces, and, if wiped on or wrung between two gauges, will cause nasty burrs. Burrs on the surfaces of the gauges

are on no account to be touched, as it is almost impossible to remove a surface burr with a piece of abrasive stone without further damaging the surface.

8. Reconditioning Service.

The National Standards Laboratory conducts a two-day reconditioning service for burred slip gauges. Gauges left one morning may be called for during the afternoon of the following day.

9. Wringing of Gauges.

Slip gauges should be handled on a clean piece of chamois mounted on a square of wood placed in a box provided with a lid, shown in Figs. 14 and 15.

Fig. 14 (left).—Slip gauge tray.
Fig. 15 (right).—Component parts.

The clean gauges to be wrung should first be wiped on a piece of prepared chamois, to provide the wringing film. Preparation of the chamois is as follows:—Clean chamois is soaked in a solution of ½ fluid ounce (or 4 level teaspoons) of vaseline in a pint of white spirit. The chamois is then squeezed and hung up to dry in a dust-free atmosphere. If the chamois be backed with singlet cloth, it will serve to distinguish the side used on slip gauge surfaces and prevent handling on that side.

Caution.—The solution of vaseline in white spirit is very slow, and it is advisable to start making up the solution a few days before it will actually be needed.

Fig. 16 (left).—Wiping with prepared chamois to provide wringing film.
Fig. 17 (right).—Placing the gauges together.

After wiping the wringing surfaces of the two gauges, as in Fig 16, they are slid over one another with light pressure and swung into position as illustrated in Figs. 17, 18, 19.

Smaller gauges should be wrung to larger gauges, and if two or more thin gauges are to be wrung to a combination, they should be added separately and not wrung together first. When a combination is completed, both the work to be checked and the slip gauge combination should be left on a clean surface-plate to come to a steady temperature. Gauges should not be left wrung over-night. When gauges are to be separated care should be taken to slide the gauges apart. No attempt should be made to break a wrung joint.

Fig. 18 (left).—Sliding the surfaces across one another.
Fig. 19 (right).—Swinging into position.

10. Note on Chamois Leather.

Chamois leather for slip gauge work should be bought from a dealer who will guarantee that it is free from silica or other abrasive. Some chamois is deliberately impregnated with silica for the purpose of imparting a high gloss in polishing glass. The chamois from the gauge tray should be washed frequently in warm (not hot) water and flake soap, being well rinsed afterwards to remove all trace of soap which, if left in, may corrode the gauges, and should be dried in a dust-free atmosphere for at least three days before use. The chamois for wringing is then treated as directed previously.

11. Substitute Solvents.

Shell Solvents X40 and X55 have been found satisfactory as substitutes for benzoline.

The white spirit mentioned above is a kerosene fraction and not ethyl alcohol which is sometimes sold under the name of "white spirit."

12. Summary of Precautions.

(1) Use slip gauges only when a coarser means of measurement is not sufficiently accurate

(2) A slip gauge, worn beyond specification limits for flatness and parallelism, is useless and usually unreclaimable.

(3) One person only should wring and unwring combinations.

(4) Handle slip gauges over a soft surface such as the tray described above.

(5) Grit-free surroundings are essential in the handling and wringing of slip gauges.

(6) Cleanliness of all surfaces coming in contact with slip gauges is essential.

(7) Always test for burrs those surfaces on which slip gauges are to be used.

(8) Burrs should always be removed before wringing slip gauges. A burred slip gauge will cause more burrs.

(9) Surface burrs should not be removed in the tool-room.

(10) Place combinations and work on a surface plate to cool.

(11) Combinations should be left wrung no longer than necessary.

(12) Separate slip gauges by sliding.

(13) Clean the gauges well before greasing.

Responses of Plants to Molybdenum in Pot Experiments on the Cressy Shaley Clay-Loam.

By C. G. Stephens, M.Sc., A.A.C.I. and A. C. Oertel, M.Sc., A.A.C.I.**

Summary.

This paper records the response of subterranean clover, perennial ryegrass, and white clover to small additions of molybdenum in pot experiments with the Cressy shaley clay-loam. It is also shown that availability of molybdenum increases in passing from acid to alkaline soil reaction values. Spectrochemical analysis of the harvested material indicates a minimum requirement of one part of molybdenum per million of dry material for normal growth of the above plants.

The Cressy shaley clay-loam (1), which contains lateritic ironstone gravel and the clay of which is kaolinitic in character, is probably unique in Australia in its power to revert superphosphate. Previous pot experiments (1) on this soil have dealt with this quality and aimed to show the method of minimizing this agricultural defect. It was demonstrated that because of high PO_4 anion exchange at the pH value of the unaltered soil, superphosphate was rendered unavailable to subterranean clover, but if the soil reaction was raised to between pH 7 and pH 8, the plants grew normally owing to the more favourable direction of the $PO_4 \leftrightarrows OH$ anion exchange and the resultant adequate supply of phosphate.

On page 25 of the publication referred to above it is stated for various reasons that "a minor element deficiency may also be involved particularly on the lighter soils . . . ." The present paper records the response of subterranean clover, perennial ryegrass, and white clover to very small additions of molybdenum salts in pot experiments with the Cressy shaley clay-loam at the Waite Agricultural Research Institute in 1942 and 1943.

Circumstantial evidence that molybdenum is an essential element in plant nutrition has been gathering for more than a decade. From 1930 Bortels (2) has shown the influence of traces of molybdenum on the nitrogen-fixing organisms. More recently, Ferguson, Lewis, and Watson (3) have shown that the teart disease of cattle in parts of the British Isles is due to *excess* of molybdenum in the herbage. In 1939, Arnon and Stout (4) showed that a trace of molybdenum was necessary in the nutrient solution for normal growth in tomato seedlings. Bertrand, in 1939 (5), published a survey of the molybdenum content of various plants. Dmitriev (6) has demonstrated the effect of molybdenum on the seed yield of red clover, and Bobko and Savvina (7) showed the necessity for traces of molybdenum for peas in water culture. In 1940, Piper (8) demonstrated the necessity of molybdenum in water culture for oats to form grain. Jensen and

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Betty (9) obtained results with lucerne which suggest that molybdenum is needed not only for general plant nutrition but also for the specific process of nitrogen fixation.

Spectrochemical analysis has proved of particular value in the experiments recorded in this paper and also previously in determining that molybdenum was present in the water-soluble and insoluble fractions of wood ashes, both of which give responses on the Burbrook sandy loam at Meadows in South Australia. Subsequently, Anderson (10) obtained field responses to molybdenum by subterranean clover pastures on that soil type. It has also been demonstrated that in many lateritic ironstone gravel podsols, such as the Burbrook sandy loam, the molybdenum content of the soil is largely concentrated in the gravel. The gravel of the Cressy shaley clay-loam is, however, low in molybdenum.

The present series of experiments was carried out in circular enamelled pots 6 inches in diameter and holding approximately 4 kilogrammes of moist soil. The soil was maintained at 70 per cent. of its water holding capacity. Fine quartzite gravel was used as a surface mulch.

The first experiment consisted of four pots growing subterranean clover, all receiving 0·69 g. of superphosphate per pot. In addition two pots were treated with 2·5 milligrammes of ammonium molybdate each. These two treated pots gave a mean yield of 8·75 g. of oven-dry material and the two untreated pots a mean yield of 7·4 g. The harvested material from the molybdenum-treated pots contained two parts per million of molybdenum, and from the untreated pots 0·5 parts per million of molybdenum. On the untreated pots the subterranean clover was pale-green in colour and on the treated plots intensely dark-green. The reaction of the surface half-inch of soil from all four pots fell in the range pH 5·70 to pH 5·75. Fricke (11) has obtained somewhat similar results in pot experiments at the Cressy Experimental Farm in Tasmania. He obtained small and consistent but statistically non-significant responses to molybdenum with subterranean clover.

Following the above observational result, experiments with perennial ryegrass and white clover were carried out on the aftermath yield of twenty pots which had been used during 1942 for an experiment involving treatments with superphosphate and agricultural lime. This experiment had been done in duplicate and in the subsequent molybdenum experiment the element was added in the form of 2·5 mg. of sodium molybdate to the odd numbered pots, the even numbers being kept as controls. The details of these two experiments and their results are set out in Tables 1 and 2, and Figs. 1 and 2 show the results in graphical form.

For spectrochemical analysis the oven-dry plant material was broken into very small pieces by hand and put in silica basins. Chemically pure concentrated sulphuric acid was added to each sample at the rate of one millilitre of acid to each gramme of dry material. Each lot was mixed and allowed to stand overnight. The excess acid was removed by heating slowly over open radiation electric heaters, the temperature

being raised gradually until all excess acid had been removed. The remaining charred material was broken into small pieces and each sample was ashed at incipient red heat for three hours.

The sulphated ashes were weighed and thoroughly mixed by use of an agate mortar and pestle. Equal amounts of the ashes were put into prepared graphite electrodes and an arc spectrogram of each sample was obtained under as nearly as practicable identical conditions.

TABLE 1.—EXPERIMENT WITH PERENNIAL RYEGRASS.

Pot No.	Treatment. 25.5.42.	Treatment. 22.10.42.	Yield in g., Oven Dry. 30.12.42.	Molybdenum Content in Approx. p.p.m. Dry Weight.	Reaction of Surface Half Inch of Soil (pH).	Remarks *re* Colour.
41	.. ..	N Mo	5·3	1+	5·21	
43	S ..	N Mo	7·1	2—	5·28	
45	S L_1	N Mo	6·4	2—	6·48	
47	S L_2	N Mo	6·3	2	7·68	No differences in colour noted.
49	S L_3	N Mo	3·1	3+	7·89	
42	.. ..	N ..	5·1	0·3	5·20	
44	S ..	N ..	6·0	0·3	5·29	
46	S L_1	N ..	5·2	0·3	6·39	
48	S L_2	N ..	5·9	0·3	7·55	
50	S L_3	N ..	4·1	0·4	7·95	

A set of standard spectrograms of synthetic plant ashes was available and these were used to estimate the concentration of molybdenum in the samples. Different standards for the grasses and clovers should have been used for accurate results; and the units of approximate parts per million may be considerably in error. However, relative values were more important in this case and these will not have errors greater than the usual errors associated with the method of analysis used, i.e., ± 20 per cent.

TABLE 2.—EXPERIMENT WITH WHITE CLOVER.

Pot No.	Treatment. 25.5.42.	Treatment. 22.10.42.	Yield in g., Oven Dry. 5.2.43.	Molybdenum Content in Approx. p.p.m. Dry Weight.	Reaction of Surface Half Inch of Soil (pH).	Remarks *re* Colour.
21	.. ..	Mo	7·3	3—	6·15	
23	S ..	Mo	9·4	4	6·10	All dark green in colour.
25	S L_1	Mo	10·4	4+	7·16	
27	S L_2	Mo	9·9	6+	7·91	
29	S L_3	Mo	9·8	10—	8·05	
22	.. ..	..	5·9	0·5	6·15	
24	S ..	..	7·4	0·5	6·09	Increasing intensity of greenness.
26	S L_1	..	9·6	0·7	7·20	
28	S L_2	..	9·8	0·8	7·97	
30	S L_3	..	9·5	1·0	8·20	

$L_1 = 1·15$, $L_2 = 4·6$, $L_3 = 13·8$ g. of agricultural lime per pot.
S = 0·69 g. of superphosphate per pot.
N = 0·5 g. of $(NH_4)_2SO_4$ per pot.
Mo = 2·5 mg. of sodium molybdate per pot.

In the experiment with perennial ryegrass there is at each pH value a consistently greater yield of, and molybdenum content in, the harvested material from the molybdenum treated pots. Also, with rise in pH value there are indications of a rise in Mo content of the plant material in both treated and untreated pots. Excluding the pots receiving no superphosphate, there is a tendency for yields to fall with increase in pH value.

In the white clover experiment there is at each pH value a consistently greater yield of, and molybdenum content in, the harvested material from the molybdenum treated pots. As shown in Fig. 2, differences in yield become less with increase in pH value and virtually disappear at pH 8. In both treated and untreated series there is a rise in molybdenum content of the clover with increase in pH value, although the maximum yield of herbage occurs at a reaction somewhat less than pH 8, probably because the optimum reaction for white clover is nearer to pH 7.

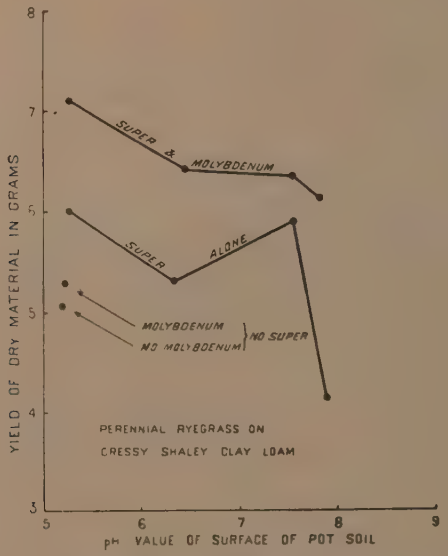

FIG. 1.—Graphs showing the effect of molybdenum on the yield of perennial ryegrass growing in pot experiments on the Cressy shaley clay-loam.

A comparison of the above white clover and molybdenum experiment with the subterranean clover and phosphate experiments described in Coun. Sci. Ind. Res. (Aust.) Bull. No. 150 show somewhat parallel features. Just as phosphate sufficient for optimum growth can be released from the soil by increasing the OH concentration, so it appears that a similar anion exchange of the type of $MoO_4 \rightleftarrows OH$ is involved in the case of molybdenum.

One part per million on a dry weight basis appears to be necessary for normal plant growth, and 0·5 p.p.m. is too little in the case of the plants used in the above experiment.

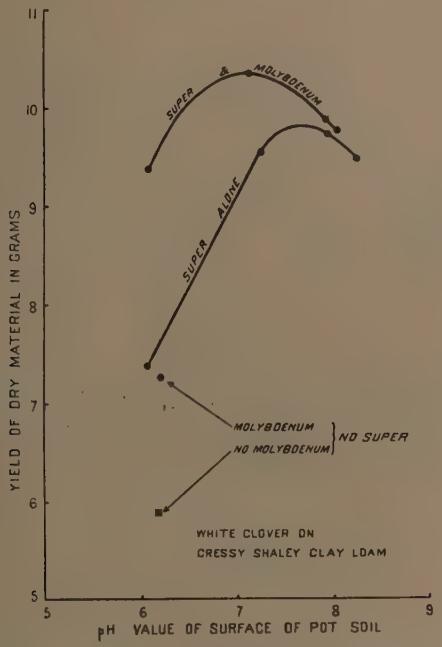

FIG. 2.—Graphs showing the effect of molybdenum on the yield of white clover growing in pot experiments on the Cressy shaley clay-loam.

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A Proposed Classification of Soil Colour.

*By J. K. Taylor, B.A., M.S., B.Sc.Agr.**

Summary.

The significance of colour definition is discussed with some of the difficulties of field estimation. Data showing lack of agreement between observers in New Zealand and Australia are discussed. A colour classification embracing 23 terms is put forward as a move towards simplification. The colour composition of these standard soil colours as determined with four Munsell discs (black, white, yellow, and red) as used by American workers is given, together with permissible range in components for each colour. These data are recalculated to the bases of quality co-ordinates or trichromatic co-efficients laid down by the Commission Internationale d'Eclairage. The co-ordinates with true wave-length purity and relative brightness are tabulated.

I. Introduction.

The question of soil colour description and the means of defining it has been investigated during the past fifteen years by workers in many countries, particularly in the United States of America. The literature has been sufficiently summarized with bibliography by Shaw (1937), Coutts (1937), and Rice *et. al.* (1941).

The method of approach in defining colour has been along four lines. (1) Comparison with printed colour standards such as those of Ridgway, Ostwald, or Munsell. The Ridgway and Ostwald standards have not found favour, but recently the United States Department of Agriculture Division of Soil Survey, co-operating with a colour technologist, has produced a set of 57 colours considered sufficient for defining all common soil colours. (2) Matching in a tintometer, which has shown promise (Coutts, 1937), does not seem to have been followed up; it was not investigated by the writer. (3) The spectrophotometric method, which is the fundamentally sound approach; unfortunately the apparatus is too expensive for general use.† (4) Matching by spinning together segments of four standard Munsell discs, which has been the most widely used method. There is no published record of the use of a trichromatic colorimeter for standardizing soil colour although it should offer a good means of definition.

An attempt has been made with the aid of the spinning Munsell discs to formulate a colour system and classification conforming to the ideas of a group of soil surveyors in Australia. Shaw (1937) has published some average figures and permissible ranges in colour composition for Californian soils by this method, but these are not comparable with those arising from the present investigation. This may be due to the preparation of the soil discs by a different method giving variable results, or to lack of agreement in colour description of the soil samples, or to differences in colour vision of the observers.

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† Preliminary measurements by this method have been made by J. A. Prescott at the Waite Institute, and it is hoped ultimately to define Australian soil colour standards with precision.

2. Significance of Colour in Soil Description.

Colour is used in all soil descriptions and is a useful diagnostic feature in distinguishing soil types. On the other hand, soil colours are not so very helpful in a practical sense as an indication of agricultural value, and it is very doubtful if it is worth while using a multiplicity of colours in description. The move should be definitely towards a small number of colour groups and a recognizable gradation within the groups. It is the essential redness or brownness or greyness or yellowness of the soils which is important. It is of small importance endeavouring to distinguish accurately where a greyish-brown changes to a brownish-grey, a greyish-yellow to a yellowish-grey, or a brownish-red to a reddish-brown. An observer cannot classify soil types on such fine distinctions. Texture is adequately described in not more than twelve terms, and it is suggested that a limited number of terms is necessary to cover general colour requirements. In a later section a list is advanced as a step towards simplification.

3. Colour Estimation in the Field.

Since some of the investigators attacking the problem of colour definition may not have had wide experience of field conditions, it may be as well to emphasize some of the practical difficulties of the estimation in the field which immediately indicate the undesirability of extreme precision in such an unprecise matter. Wetness or dryness is the obstacle most frequently quoted, although as a rule it presents no great difficulty to an experienced surveyor. The quality of the light is particularly important. It is very difficult to do justice to soil colour with the sun dipping towards the horizon or on a very dull day. The degree of pulverization of the soil interferes, and a hard-baked dry surface with a film of fine dust dulls the colour greatly. Cloddiness darkens the general effect with a shadow pattern. Mottling is difficult to describe exactly, especially as uncommon shades come in, such as blue or green, which on complete air-drying lose their characteristic clearness. Blueish-greys become merely grey, and grey may move towards brownish-grey. The observer should mention the main colour and the mottling adding the apparent fresh colours of the inclusions; these will certainly change by the time the sample reaches the laboratory. Intermediate colours are often due to the mixing of more distinct colours on boring with an auger.

There are so many factors militating against clear description that it is better not to attempt to define hairsplitting differences. As field work has to be carried on under a wide range of atmospheric conditions and with reasonable speed, a colour classification needs to be simple, especially as minor differences in shade are not important in characterizing a soil.

4. Disagreement between Observers in Soil Colour.

Coutts (1937) has stated the differences in results obtained by two observers in matching soil colours with the spinning Munsell discs. Schofield (1938) has explained the discrepancies and probable errors involved. The same situation arose in a comparison of readings made in Wellington (New Zealand) and in Adelaide (Australia) by observers using the same soils and later even the same soil discs. The lack of

agreement was not so marked in certain colours such as light-grey and black, but was very great in others. The remarkable feature was the consistently lower black and higher white values which would seem to indicate either a radical difference in light intensity or be due to a personal factor. Some comparative readings are given in Table 1.

TABLE 1.—COMPARISON OF READINGS OF COLOUR COMPOSITION OF THE SAME SOILS USING MUNSELL DISCS IN AUSTRALIA AND NEW ZEALAND.

Description of Soil Colour.	Observer.	Colour Composition by Munsell Discs.				Red + Yellow / Yellow
		Black N. 1.	White N. 9.	Yellow 8/8.	Red 4/9.	
		%	%	%	%	%
Light grey ..	N.Z. ..	41	34	15	10	1·7
	Aust. ..	45	28	16	11	1·7
Grey ..	N.Z. ..	33·5	27·5	21·5	17·5	1·8
	Aust. ..	44	20·5	22	13·5	1·6
Black ..	N.Z. ..	86·5	8·5	2	3	2·5
	Aust. ..	87	6·5	3·5	3	1·9
Greyish yellow	N.Z. ..	32	8	31	29	1·9
	Aust. ..	50·5	4·5	24·5	20·5	1·9
Yellow ..	N.Z. ..	19	9	39	33	1·9
	Aust. ..	37	5	34	24	1·7
Yellow-brown	N.Z. ..	31	0	21	48	3·3
	Aust. ..	49·5	0	17	33·5	3·0
Brown ..	N.Z. ..	45	6	19	30	2·6
	Aust. ..	53·5	5	16·5	25·5	2·5
Dark brown ..	N.Z. ..	67	1	9	23	3·6
	Aust. ..	72·5	1·5	8·5	17·5	3·0

The comparison of these sets of readings could not be viewed with optimism, but there was no evidence that both observers had standard colour vision or equivalent lighting as both worked by daylight. On the other hand it is usual to have three observers in Adelaide agree with the matching sufficiently closely to allow hope for standardization under the conditions existing there. In this hope the classification was continued, assuming that those concerned all had standard vision. The Adelaide matching was always done with light which was always bright from a clear sky.

5. Preparation of Soil Discs.

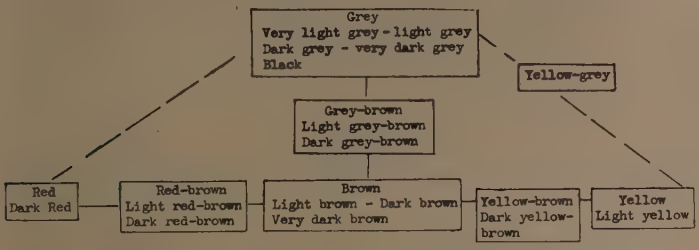
Soil discs were prepared which would stand considerable handling while showing the original colour of the soil. The comparison of lumps of soil with the spinning disc was unsatisfactory, and Shaw's method of painting the soil as mud on to filter paper was also not favoured because of the smoothed surface and the fragility of the disc. The method adopted was to stick an entire coat of soil to a cardboard disc with hot glue. Colourless duco is almost as good an adhesive. The soil

was gently pestled if necessary and put through a 0·5-mm. sieve, returning the residue to the sample for final mixing. There is not a great difference in colour reading in using the 2-mm. sieved soil, but in pestling aggregates are broken up sufficiently finely to remove any fine shadow pattern. On the other hand, continued or finer grinding lowers the black and increases the white component in matching. The soil should cover the glue completely. Very sandy soils usually give trouble in making good discs.

Some difference exists between the colour of the field sample and the ground material, but it is generally necessary to do some grinding on laboratory samples. The colour of the original soil in the field was unfortunately not available for many of the soils used, or was not reliably described. The 2-mm. samples in the storage bottles were examined and described by the writer and checked by competent observers in a number of cases. The colours were matched against the spinning Munsell discs. The following scheme is suggested as a basis for discussion.

6. Classification of Soil Colours.

The proposed system consists of brown, red, grey, and yellow series with intermediates, and each colour may be qualified by terms "light" or "dark" and the adverb "very." The brown is a kind of focal colour in soil description as illustrated in the following arrangement.



No white is included as it is extremely rare to find this colour, unless for example very high amounts of calcium carbonate are present. There should be a group between the red and grey groups; this would be a "chocolate" colour but its occurrence is uncommon outside basaltic soils. Other qualifying terms are frequently used, such as drab, dull, bright, to characterize the field appearance. As a standard it was thought better to deal only with accepted colour terms rather than include some which may be very useful in practice, such as "fawn." Terms such as in Ridgway's colour atlas are inadvisable. The colour standards published by the U.S.D.A. soil survey should be a sound category based on long experience. These will need time to be tested as also the new method of description.

In the groups set out above it is intended that the grey-brown, red-brown, yellow-brown, and yellow-grey groups should have a significant value instead of the range between the main series being divided into a gradation of colours. Near brown and near grey are not significantly different on pedological or agricultural grounds from the brown and grey. Instead of debating the distinction of when a greyish-brown passes

to a brownish-grey it appears better to define an intermediate colour and, if so desired, indicate trends to the grey (or brown) extreme by describing as grey-brown to grey (or brown). The same treatment is given the other intermediate groups.

There are some omissions, as, for example, no light yellow-brown is included, and the abverb "very" might have been used in some additional cases. These have not proved necessary or have been confusing in practice.

7. Colour Composition of Proposed Colour Classes.

Using the method of Shaw (1932) of matching soil colours with the four Munsell discs—Black, Neutral 1; White, Neutral 9; Yellow 8/8; Red 4/9—the colour classes named in the preceding section show the proportions set out in Table 2. It will be seen that the figures given for red, dark-red, and dark red-brown are in doubt owing to the continuous difficulty met in matching them closely.* It is certain that both would show a ratio of red + yellow to yellow of at least 3·5 (column 7). Another colour occasionally giving trouble in matching was yellow-brown. As Coutts pointed out from experience in South Africa, these difficult soils have a very low or zero white component.

TABLE 2.—COLOUR COMPOSITION OF CERTAIN STANDARD SOIL COLOURS USING MUNSELL DISCS.

Soil Colour.	Number of Samples.	Colour Composition Per Cent.				Red + Yellow / Yellow
		Black No. 1.	White No. 9.	Yellow 8/8.	Red 4/9.	
Black	10	87·5	6	3	3·5	2·2
Very dark grey..	10	79·5	8·5	6·5	5·5	1·8
Dark grey ..	17	69·5	14	9	7·5	1·8
Grey	10	57·5	19	13·5	10	1·7
Light grey ..	10	44·5	25·5	18	12	1·7
Very dark brown	13	79	0 +	8	13	2·4
Dark brown ..	9	72·5	1	9·5	7	2·8
Brown ..	18	56·5	4	16	23·5	2·5
Light brown ..	16	42	9	19·5	29·5	2·5
Dark grey–brown	14	75·5	5	9·5	10	2·0
Grey–brown ..	17	57	11	15	16	2·1
Light grey–brown	16	44	14	20·5	21·5	2·0
Yellow.. ..	10	45·5	4·5	26	24	1·9
Light yellow ..	10	23	12·5	36	28·5	1·8
Dark yellow–brown	6	50·5	0·5	18·5	25·5	2·4
Yellow–brown ..	13	34·5	3	27·5	35	2·3
Dark red* ..	6	63·5	0	8·5	28	4·3
Red*	6	48	0	11·5	40·5	4·5
Dark red–brown*	8	70·5	0	8·5	21	3·5
Red–brown ..	13	66	0 +	10	24	3·4
Light red–brown	11	44	1·5	16	38·5	3·4

* Results approximate only due to imperfect matching.

* It has been suggested by Schofield (see Coutts, 1937) that the inclusion of a segment of white with the red soil discs would permit of matching. This

Actually nearly all the reddish soils matched showed a zero white as a standard feature. This does not seem to be the case with soils described as red or red-brown in America. Possibly the degree of redness on Australian standards is not considered necessary elsewhere or workers may have more consistently dealt with less red material. The method of preparation of the disc or matching technique may have assisted towards a satisfactory reading not achieved in the present work.

Table 3.—Permissible Limits for Components in Colour Groups.

Soil Colour.	Black N. 1.	White N. 9.	$\frac{\text{Red + Yellow}}{\text{Yellow}}$	Remarks.
Black	> 85	4– 8	Abt. 2·0	White always > yellow or red often = sum
Very dark grey ..	75–85	8–12	,, 1·8	White always > yellow or red
Dark grey ..	65–75	10–20	,, 1·8	White generally > yellow or red
Grey	50–65	15–20	,, 1·7	White generally > yellow or red
Light grey ..	40–50	20–35	,, 1·7	White always > yellow or red
Very dark brown	75–80	0– 4	Abt. 2·6	White always < yellow or red
Dark brown ..	65–75	0– 4	,, 2·8	White always < yellow or red
Brown	50–65	2– 8	,, 2·5	White always < yellow or red
Light brown ..	35–50	5–12	,, 2·5	White increasing but < yellow or red
Dark grey–brown	70–80	4– 8	Abt. 2·0	White generally < yellow or red
Grey–brown ..	50–70	8–12	,, 2·1	White generally < yellow or red
Light grey–brown	35–50	12–20	,, 2·0	White generally < yellow or red
Yellow	35–55	1–10	Abt. 1·9	White low, never zero
Light yellow ..	15–35	10–20	,, 1·8	White medium, black low
Dark yellow–brown	50–60	0– 2	Abt. 2·4	White very low. Some imperfect matching
Yellow–brown ..	25–50	0– 5	,, 2·3	White low
Dark red–brown	65–75	0	Abt. 3·5	White zero. Frequent imperfect matching
Red–brown ..	55–75	0 +	,, 3·4	White generally zero
Light red–brown..	30–55	0– 4	,, 3·4	White sometimes zero
Dark red ..	60–70	0	> 3·5	White zero. Usually imperfect matching
Red	40–55	0	> 3·5	White zero. Usually imperfect matching

It was possible to work out a permissible range of the four components for the colour groups using the large number of readings available. This is given in Table 3 with comments on the amount and proportion of the components.

was tried with three soils of proved difficulty in matching using a disc of bristol board as the white component. The following results are typical:—

Soil Colour—dark-red.

	Black.	*White.*	*Yellow.*	*Red.*
Soil disc		no match		
Soil disc with 3% white ..	71·5	0	5·5	23
Soil disc with 5% white ..	69	2·5	5·5	23
Soil disc with 7% white ..	65·5	6	5·5	23

The 3 per cent. white inclusion was not perfect match; the 5 per cent. and 7 per cent. inclusions were very good.

The average colour composition for the standard in each group (Table 2) is represented on a triangular diagram using 100 per cent. black, white, and colour as the apices. The ratio of total colour (red + yellow) to yellow is given for each colour to show the difference between adjacent colours in the triangle.

The trend of increasing lightness in the different series of colours is brought out by the linear arrangement of the plotted points which are joined on the diagram. (Fig. 1.)

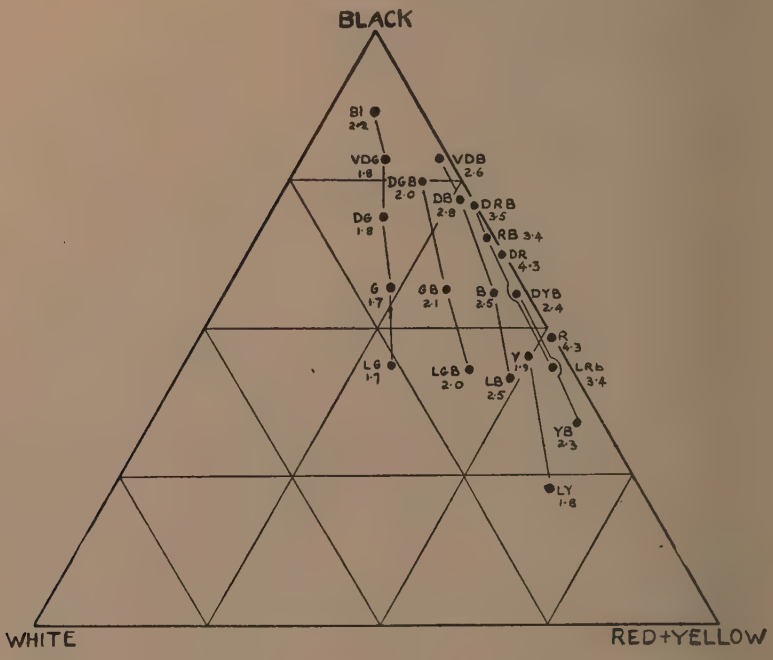


Fig. 1.—Triangular diagram illustrating colour composition of standard soil colours in terms of percentage black, white, and colour (standard Munsell discs). Bl = black: VDG = very dark grey: DG = dark grey: G = grey: LG = light grey: DGB = dark grey-brown: GB = grey-brown: LGB = light grey-brown: DB = dark brown: B = brown: LB = light brown: DRB = dark red-brown: RB = red-brown: LRB = light red-brown: DR = dark red: R = red: Y = yellow: LY = light yellow: DYB = dark yellow-brown: YB = yellow-brown.

8. Comparison of Colours with the Standards of the U.S.D.A. Soil Survey.

A range of prepared soil discs representing the main colours described above have been compared with the printed colour standards set out in the publication by Rice *et. al.* (1941). The nearest equivalents to them are as follows:—

Colour.	*U.S.D.A. Soil Survey Standard.*
Brown	Moderate brown, sometimes light brown towards moderate brown.
Light brown ..	Light brown, sometimes between light brown and light yellow-brown.
Dark brown ..	Moderate brown, sometimes weak reddish-brown.
Very dark brown ..	Moderate brown towards dark brown.
Red	Moderate reddish-brown.
Red-brown ..	Weak reddish-brown.
Dark red-brown ..	Moderate reddish-brown towards dark reddish-brown.
Light red-brown ..	Dark orange towards moderate orange—may tend towards moderate brown.
Black	Black.
Very dark grey ..	Dark grey towards brownish-grey.
Dark grey	Light olive-grey towards light brownish-grey.
Grey	Light brownish-grey (?).
Light grey ..	Light brownish-grey towards very pale brown
Grey-brown ..	Pale brown towards light yellow-brown.
Light grey-brown ..	Light yellow-brown.
Dark grey-brown ..	Brownish-grey towards weak brown.
Yellow	Moderate yellow-brown towards light yellow-brown.
Light yellow ..	Light yellow-brown towards light-yellow.
Dark yellow-brown ..	Moderate yellow-brown towards moderate brown.
Yellow-brown ..	Light yellow-brown (?).

All these comparisons are on completely dry soil samples in the laboratory; with any moistening of the samples, the colours would darken and increase in chroma.

9. Representation of Standard Soil Colours by C.I.E. Coordinates.

Schofield (1938) has discussed the recalculation of soil colour readings made with Munsell discs to the basis of the co-ordinates established by the Commission Internationale d'Eclairage. On the assumption that the light used in Adelaide was equivalent to International Standard Illuminant C, or that the error involved was small in comparison with those arising from other factors during the matching, the data for the colour groups in Table 2 were recalculated—Table 4.

The colour series show a definite difference. In some cases the grouping is very good as in the brown—grey-brown—grey sequence. This relation is brought out better by plotting the x and y co-ordinates on a chromaticity diagram to demonstrate graphically the hue and purity of the colour series.

In the case of grey-brown and red-brown they appear as an additive mixture of grey and brown or red and brown but this does not apply to other intermediate colour groups as yellow-brown. It is possible to imagine a gradation of intermediate colours between brown and grey, red, or yellow and between grey and yellow so that their plotted co-ordinates are arranged linearly between these extreme colours. The grey-brown and red-brown are examples. The yellow-browns are

difficult to match and are tending towards an orange colour. The matching of these and all red soils would be readily possible with the substitution of a different yellow disc approaching an orange.

TABLE 4.—QUALITY CO-ORDINATES (TRICHROMATIC CO-EFFICIENTS) OF STANDARD SOIL COLOURS.

Series.	Group.	Quality Co-ordinates.			Relative Brightness.
		x.	*y.*	*z.*	
Grey	Black	·3396	·3392	·3211	8·4
	Very dark grey ..	·3494	·3494	·3011	12·4
	Dark grey ..	·3477	·3483	·3039	17·9
	Grey	·3504	·3517	·2971	24·3
	Light grey ..	·3504	·3527	·2970	31·7
Brown	Very dark brown	·4105	·3794	·2101	8·0
	Dark brown ..	·4090	·3760	·2149	10·0
	Brown	·4028	·3779	·2191	16·5
	Light brown ..	·3912	·3712	·2376	22·7
Grey–brown ..	Dark grey–brown	·3745	·3656	·2600	12·0
	Grey–brown ..	·3715	·3635	·2650	20·1
	Light grey–brown..	·3750	·3666	·2584	26·0
Yellow	Yellow	·4056	·3925	·2019	22·5
	Light yellow ..	·3917	·3845	·2237	34·3
Yellow–brown ..	Dark yellow–brown	·4243	·3936	·1823	15·6
	Yellow–brown ..	·4200	·3921	·1878	23·5
Red	Dark red* ..	·4326	·3684	·1990	10·0
	Red*	·4428	·3703	·1870	13·1
Red–brown ..	Dark red–brown*	·4236	·3738	·2026	9·2
	Red–brown ..	·4273	·3765	·1960	10·3
	Light red–brown ..	·4289	·3775	·1936	16·4

* Calculations tentative due to frequent imperfect matching.

The dominant hue wave-lengths may be found directly from Fig. 2 by joining the point representing Standard Illuminant C to the point representing the colour and extrapolating to intersect the spectral locus. The dominant hue wave-lengths for all soil colour groups defined lie in the narrow range between 576μ and 589μ in the yellow portion of the spectrum. The purity of the colour is given directly by the distance of the soil point from C (Fig. 2) as a percentage of the total length from C to the spectral locus at the dominant wave-length. Table 5 summarizes the data defining certain colours representing the soil colour groups.

While the number of observers in Australia concerned with colour nomenclature is comparatively small, it is not difficult by contact or exchange of standards to achieve some uniformity in colour concept. It is very desirable to standardize colours for other technical services such as engineers or architects dealing with and classifying soil materials; checking work along the same lines as this paper would be advantageous.

TABLE 5.—HUE, PURITY, AND QUALITY CO-ORDINATES OF REPRESENTATIVE SOIL COLOUR GROUPS.

Colour.	Hue Wavelength. μ	Purity. %	Quality Co-ordinates.	
			x.	y.
Brown	584	41	·4028	·3779
Grey-brown	581	18·5	·3737	·3652
Grey	576	31	·3504	·3517
Red-brown	587	48	·4273	·3765
Red*	589	42	·4428	·3703
Yellow-brown	582	50	·4200	·3921
Yellow	580	48·5	·4756	·3925

* Approximate calculation only.

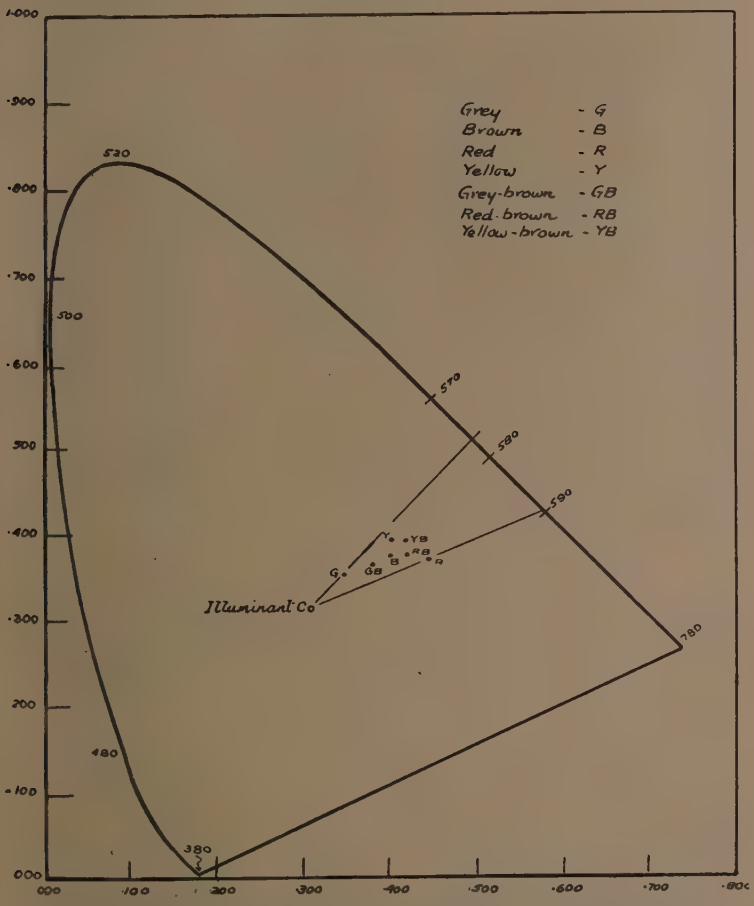


FIG. 2.—Chromaticity diagram illustrating location of illuminant C and the standard soil colour series in relation to the locus of spectrum colours.

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Insect Transmission and Host Plants of Virescence (Big Bud of Tomato).

*By A. V. Hill, M.Agr.Sc.**

Summary.

1. Virescence (Big Bud of tomato), a virus disease, was transmitted by the jassid *Thamnotettix argentata* Evans to 23 species of plants of 13 families.

2. Virescence similar to that obtained by grafting and insect transmission was observed occurring naturally on 65 species in 24 families.

1. Introduction.

In Australia, big bud of tomato was reported (5, 6) on tobacco, eggplant, black nightshade, and thornapple, whereas in the U.S.S.R., the host range of virescence, which was considered by Ryjkoff (8) to be the same disease, included tobacco, tomato, chilli, *Convolvulus arvensis, Atropa Belladonna, Datura* spp., and other members of the *Solanaceae.* What appears to be the same or a closely related disease was reported in south India by Thomas and Krisnaswami (9) on brinjal (*Solanum melongena*) and *Datura fastuosa,* and was transmitted by grafting to tomato, tobacco, *D. fastuosa,* and *Solanum trilobatum,* and by the jassids *Eutettix phycitis* and *Empoasca devastens,* the former being the more effective vector. Dana (1) reported the occurrence of big bud of tomato in the Pacific north-west of the U.S.A., and transmitted the disease from tomato to tomato by grafting. He also stated that "Phyllody similar to that produced in tomato by big bud has occurred on common bean, lima bean, soybean, alfalfa, sweet clover, carrot, and squash." In Australia, virescence or "greening" of cultivated plants has been observed for many years, and its occurrence on marigolds, Iceland poppies, phlox, antirrhinum, asters, and sunflowers in New South Wales has been reported (3). Enlargement of the calyx, a symptom that led to the adoption of the name "big bud" for the disease in tomato, does not always occur, but virescence or greening of floral parts is characteristic, therefore virescence is considered a better name for the disease.

Big bud of tomato and virescence in some other plants appear to be due to the same virus, and, if this be so, the virus has a wide host range. The observed natural occurrence of virescence and its transmission by the jassid *Thamnotettix argentata* Evans to a number of plants in different families is reported in this paper.

2. Occurrence.

Virescence occurs in a wide range of host plants, including the annuals, perennials, and shrubs listed in Table 1, the symptoms of the disease being similar to those produced experimentally. It usually appears after mid-December, but occurs in summer-flowering annuals as early as November. At Canberra, in 1941-42, more than 50 per cent. of annual aster plants were diseased. The disease was not observed in spring-flowering annuals, but if abnormal conditions caused such

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plants to grow during summer, virescence occurred in some species. *Erodium* spp. growing in Canberra after the heavy summer rains in 1940-41 became virescent, whereas these plants are unaffected during the normal growing season of March–October.

Biennial and perennial plants that are commonly affected at Canberra include cats-ear, wild salvia, antirrhinum, and white clover (*Trifolium repens*). At Mossvale, N.S.W., about 100 miles north-east of Canberra, the incidence of virescence on *T. repens* during 1939-41 caused the abandonment of the single plant crossing programme. At Canberra in 1940-41, in experiment plots containing *Hyoscyamus niger, Digitalis lanata,* and *Atropa Belladonna,* the percentages of infection with virescence were 60, 30, and 12 respectively. Spread of the disease by vegetative propagation of infected plants prior to the appearance of symptoms was observed in chrysanthemum and dahlia. Usually, the first flowers produced by infected spring-flowering perennials, and sometimes flowers produced in late autumn, appeared healthy, but during the warmer period all were virescent. In most plants symptoms occur mainly in flowering parts, therefore in some biennials the presence of the disease may not be evident during the first season. This is important where crops such as parsnip, carrot, and celery are grown for seed.

TABLE 1.—LIST OF PLANTS NATURALLY INFECTED WITH VIRESCENCE.

Family.	Name of Plant.	
	Scientific.	Common.
Solanaceae	*Datura ferox* L.	Thornapple, Long-spined
Solanaceae	*Datura Stramonium* L.	Thornapple, Common
Solanaceae	*Datura Tatula* L.	Thornapple, Purple-flowered
Solanaceae	*Lycopersicon esculentum* Mill.	Tomato
Solanaceae	*Nicotiana tabacum* L.	Tobacco
Solanaceae	*Nicotiana rustica* L.	
Solanaceae	*Solanum opacum* A. Br.	Nightshade, Black-berried
Solanaceae	*Solanum pterocaulon* Dunal.	Nightshade, Creeping
Solanaceae	*Petunia* sp.	Petunia
Solanaceae	*Solanum melongena* L.	Eggplant
Solanaceae	*Atropa Belladonna* L.	Nightshade, Deadly
Solanaceae	*Hyoscyamus niger* L.	Henbane, Black
Leguminosae	*Trifolium repens* L.	White clover
Leguminosae	*Trifolium pratense* L.	Red clover
Leguminosae	*Lathyrus pubescens* Hook. and Arn.	Lathyrus
Leguminosae	*Lathyrus latifolius* L.	Perennial or everlasting pea
Compositae	*Calendula officinalis* L.	Marigold
Compositae	*Gaillardia* sp.	Gaillardia
Compositae	*Sonchus oleraceus* L.	Sowthistle, Common
Compositae	*Sonchus asper* (L.) Hill	Sowthistle, Rough
Compositae	*Hypochaeris radicata* L.	Catsear/Flatweed
Compositae	*Aster* sp.	Aster, Annual
Compositae	*Crepis taraxacifolia* Thuill.	Dandelion crepis
Compositae	*Lactuca sativa* L.	Lettuce
Compositae	*Dahlia* spp.	Dahlia
Compositae	*Cirsium lanceolatum* (L.) Hill	Spear thistle
Compositae	*Centaurea cyanus* L.	Cornflower
Compositae	*Zinnia* spp.	Zinnia
Compositae		Shasta daisy
Compositae		Chrysanthemum

TABLE 1.—LIST OF PLANTS NATURALLY INFECTED WITH VIRESCENCE.—*continued.*

Family.	Name of Plant.	
	Scientific.	Common.
Scrophulariaceae	*Antirrhinum majus* L.	Antirrhinum
Scrophulariaceae	*Verbascum virgatum* With.	Mullein, Twiggy
Scrophulariaceae	*Digitalis lanata* Ehrh.	Foxglove
Chenopodiaceae	*Beta vulgaris* L.	Beet, Common (silver beet)
Chenopodiaceae	*Beta vulgaris* L.	Beet, Red
Chenopodiaceae	*Rumex pulcher* L.	Dock, Fiddle
Chenopodiaceae	*Chenopodium carinatum* R. Br.	Goosefoot, Keeled
Umbelliferae	*Petroselinum hortense* Hoffm.	Parsley
Umbelliferae	*Daucus Carota* L.	Carrot, Common
Umbelliferae	*Apium graveolens* L.	Celery
Umbelliferae	*Peucedanum sativum* Benth. and Hook.	Parsnip
Geraniaceae	*Geranium* spp.	Geranium
Geraniaceae	*Erodium cygnorum* Nees	Crowfoot, Blue
Geraniaceae	*Erodium cicutarium* (L.) L'Hérit.	Crowfoot, Common
Labiatae	*Leonotis Leonurus* R. Br.	Lion's ear
Labiatae	*Salvia Verbenaca* L.	Sage, Wild
Caryophyllaceae	*Gypsophila elegans* Bieb.	Gypsophila
Caryophyllaceae	*Dianthus caryophyllus* L.	Carnation
Polemoniaceae	*Phlox paniculata* L.	Phlox, Perennial
Polemoniaceae	*Phlox Drummondi* Hook.	Phlox, Annual
Crassulaceae	*Cotyledon* sp.	Cotyledon
Boraginaceae	*Anchusa officinalis* L.	Alkanet
Aizoaceae	*Tetragonia expansa* Murr.	Spinach, New Zealand
Tropaeolaceae	*Tropaeolum majus* L.	Nasturtium
Convolvulaceae	*Mina lobata* Llav. and Lex.	
Ranunculaceae	*Aquilegia* sp.	Aquilegia
Ranunculaceae	*Delphinium* sp.	Delphinium or larkspur
Verbenaceae	*Verbena venosa* Gill and Hook.	Vervain, Veined
Thymelaeaceae	*Daphne* sp.	Daphne
Violaceae	*Viola* sp.	Viola
Papaveraceae	*Argemone mexicana* L.	Poppy, Mexican
Amaranthaceae	*Trichinium alopecuroideum* Lindl.	Long-tails
Plantaginaceae	*Plantago lanceolata* L.	Ribwort or Lamb's Tongue
Resedaceae	*Reseda Luteola* L.	Wild mignonette
Gramineae	*Cynodon dactylon* (L.) Pers.	Couch
Gramineae	*Phalaris tuberosa* L.	Phalaris/Toowoomba canary grass

3. Transmission Experiments.

(i) *By grafting.*—Virescence (big bud) was readily transmissible by grafting infected tomato, tobacco, eggplant, black nightshade, or common thornapple to healthy plants of each of these five species. Transmission was not obtained when scions from non-solanaceous virescent plants were grafted with healthy host plants known to be susceptible to big bud (5). However, it was obtained, by grafting, from phlox to phlox, and from antirrhinum to antirrhinum.

(ii) *By insects.*—Collections of insects were made in fields in which virescent plants were observed, and the species suspected of being vectors were placed in different cages with healthy host plants, and also in other cages with virescent tomatoes or other plants. Small-flowered mallow

and sugar beet, acceptable as breeding plants to most of the insects, were placed in each cage. Insects used in these tests were *Nezara viridula* L. (green tomato bug), *Thrips tabaci* Lind. (tobacco thrips), *Nysius vinitor* Bergr. (Rutherglen bug), and the jassids *Empoasca terrareginae* Paoli, *Eurinoscopus viridis* Evans, *Erythroneura* spp. (canary flies), and *Thamnotettix argentata* Evans. All insects except *T. argentata* failed to transmit the disease.

Transmission was first obtained with *T. argentata* collected from ornamental flowering plants at Shepparton, Victoria, *E. cicutarium* (crowfoot) becoming infected. In another cage with the same species collected in the field at Canberra, A.C.T., small-flowered mallow became virescent. Infective *T. argentata* bred on sugar beet and small-flowered mallow were used in most of the transmission tests. They were placed on single plants enclosed in organdie bags or in cages, or on several different species of plants enclosed in one cage. Control plants placed in cages containing non-infective *T. argentata* and kept under similar conditions failed to develop symptoms of the disease.

TABLE 2.—LIST OF PLANTS EXPERIMENTALLY INFECTED WITH VIRESCENCE (BIG BUD) BY *Thamnotettix argentata* EVANS.

Family.	Name of Plant.	
	Scientific.	Common.
Solanaceae ..	*Nicotiana tabacum* L. ..	Tobacco (*a*)
Solanaceae ..	*Lycopersicon esculentum* Mill.	Tomato (*a*) or (*b*)
Solanaceae ..	*Solanum melongena* L. .	Eggplant (*a*)
Solanaceae ..	*Solanum opacum* A. Br. ..	Black-berried nightshade (*a*)
Solanaceae ..	*Capsicum annuum* L. ..	Pepper (*a*)
Leguminosae ..	*Trifolium repens* L. ..	White clover (*a*)
Leguminosae ..	*Trifolium pratense* L. ..	Red clover (*a*)
Leguminosae ..	*Medicago denticulata* Willd.	Burr medic (*a*)
Compositae ..	*Sonchus oleraceus* L. ..	Sowthistle, Common (*a*).
Compositae ..	*Hypochaeris radicata* L. ..	Catsear/Flatweed (*a*)
Compositae ..	*Cryptostemma calendulaceum* R. Br.	Capeweed (*a*)
Scrophulariaceae..	*Antirrhinum majus* L. ..	Antirrhinum (*a*), (*c*), (*j*), or (*k*)
Labiatae ..	*Salvia Verbenaca* L. ..	Sage, wild
Chenopodiaceae ..	*Beta vulgaris* L.	Sugar beet (*a*) or (*c*).
Chenopodiaceae ..	*Chenopodium murale* L. ..	Nettle-leaved goosefoot (*a*)
Polemoniaceae ..	*Phlox Drummondi* Hook. ..	Phlox, Annual (*a*)
Portulacaceae ..	*Portulaca oleracea* L. ..	Pigweed/Purslane (*a*) or (*d*)
Malvaceae ..	*Malva parviflora* L. ..	Small-flowered mallow (*a*), (*e*), (*g*), or (*h*)
Boraginaceae ..	*Heliotropium europaeum* L.	Common heliotrope (*a*)
Boraginaceae ..	*Anchusa officinalis* L. ..	Alkanet (*a*)
Geraniaceae ..	*Erodium cicutarium* (L.) L'Hérit.	Common crowfoot (*a*) or (*f*)
Plantaginaceae ..	*Plantago lanceolata* L. ..	Ribwort or Lamb's Tongue (*a*)
Tropaeolaceae ..	*Tropaeolum majus* L. ..	Nasturtium (*a*)

Source of virus—(*a*) Sugar beet and small-flowered mallow; (*b*) foxglove; (*c*) capeweed; (*d*) purslane; (*e*) small-flowered mallow; (*f*) ornamentals, Shepparton, Vic.; (*g*) ornamentals and weeds, Canberra, A.C.T.; (*h*) common crowfoot; (*j*) wild sage; (*k*) tomato.

Using either nymphs or adults, virescence was transmitted to one or more plants of each species listed in Table 2, the occurrence of the disease being determined, except in sugar beet, by greening and proliferation of floral parts. Infected sugar beet seedlings produced a large number of small leaves, and eventually died without forming an inflorescence. Symptoms appeared in 24-155 days, the time interval being determined largely by the length of the period between infection and flowering, and by the season of the year. Some plants that were infected in the autumn did not develop symptoms until the following spring. Usually, one or more healthy flowers appeared on vigorous plants before greening and proliferation occurred. In many plants, onset of the disease was accompanied by the development of axillary buds into short branches bearing numerous small leaves with short petioles, the plant assuming a compact stunted appearance. Frequently, the floral axis of diseased flowers continued to elongate, and further differentiation took place until the floral axis looked like a stem with virescent flowers or clusters of small leaf-like structures at intervals along its length. (See Plate 1 and Plate 2, Fig. 1.)

4. Discussion.

Transmission of the disease was obtained by using insects, by grafting and budding, and it was also spread by vegetative reproduction of infected plants. In the field, the most important means of transmission was by insects. According to Evans (2) the vector *T. argentata* "is common on a wide variety of weeds in all States of eastern Australia", and it also occurs in Western Australia.* It was studied by Helson (4) because of its importance as a vector of yellow dwarf of tobacco (7). According to Helson, the population of this jassid reached a peak in late spring at the time that autumn-spring host plants such as capeweed and crowfoot died. This may be in November or as late as the end of December, depending on district and seasonal conditions. The insects then migrate to other host plants and the survivors begin breeding when suitable plants are available. Where irrigation is practised, or in seasons with good summer rains, host plants suitable for breeding may be available throughout the summer months. Most of the plants on which the jassids survive during summer are not acceptable as breeding plants, but many of them are susceptible to virescence. Members of the Solanaceae, on which the disease was described under the name big bud, are not liked by the jassid as feeding or breeding plants, therefore transmission from this family to others was difficult to obtain. It was transmitted readily to solanaceous plants by infective insects from virescent plants of other families. Presumably, the vector becomes infective after feeding on diseased biennials or perennials during migration, and, subsequently, transmits the disease to annual plant species. Both laboratory and field data suggest that normally infection does not take place during the cooler period of the year, or, if it does occur, symptoms are masked until the following summer. However, the absence of symptoms on autumn-spring breeding plants suggests that they remain healthy. If they were infected, the disease would be expected to appear earlier and to occur on a much higher proportion of susceptible plants.

* Collected by D. O. Norris, Nov., 1941.

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Strains of Spotted Wilt Virus and the Identity of Tomato Tip-Blight Virus with Spotted Wilt.

*By D. O. Norris, B.Sc.(Agric.)**

Early in 1941 when work was being done with spotted wilt obtained from potatoes, it was observed that the local lesions produced by inoculation on *Nicotiana glutinosa* were of several distinct types. Acting on the hypothesis that each type was produced by a separate strain of the virus, tissue selection and subtransfer was begun, after the method of Salaman (1938). In this way it was demonstrated that several, probably three, strains of virus were present. In order to show that this was the normal condition, an average sample of spotted wilt was taken at random from a Canberra garden and the work repeated. Three strains were again shown to be present. Tomato spotted wilt is thus not a virus entity but a complex of closely related strains. The well-known variation in severity of the disease is simply explained as a variation in the ratio of the strains present.

Of the three strains under selection only one, the necrotic, has so far been completely purified. The other two which are known as ringspot and mild, although not pure, have been obtained in sufficiently high concentration to enable some idea to be gained of their effect on the tomato. The ringspot produces a disease of medium severity with leaf distortion, mottle, and some stunting, but no trace of necrosis. The mild produces only slight symptoms and its possibilities for protective inoculation are to be investigated.

The necrotic strain produces on tomato a necrotic collapse spreading from the first infected leaflets into the stem and ultimately involving the whole of the upper portion of the plant. In Plate 2, Fig. 2, is shown an affected plant eighteen days after inoculation. The relative ease with which this necrotic strain was separated from the other components in the greenhouse indicates that, of the three strains, it is the most likely to become established in pure form under natural conditions. This strain appears to be identical with the virus described by Milbrath (1939) in Oregon as tomato tip blight. The symptoms produced on tomato, tobacco, and other hosts correspond closely. In Oregon this necrotic strain was apparently separated out by chance from the others, but its occurrence in close association with ordinary spotted wilt was observed. Milbrath also noted that occasionally both viruses occurred together in tomato. In such cases it would appear that other strains were present but that the necrotic strain occurred in very high concentration. In Australia, Samuel, Bald, and Pittman (1930) noted that occasionally plants which were more necrotic than usual were found, and undoubtedly these cases were similar. In Australia no tip-blight disease, indicating complete separation of the necrotic strain, has

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yet been noted. Further work is being done to confirm the identity of the two viruses.

A complete account of all work reported in this note will be published later.

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Fasciation in Cabbage.

*By S. G. Gray, B.Sc.Agr.**

An example of fasciation occurred in a batch of "Succession" cabbage plants which were grown at Canberra in 1941-42 in connexion with experimental work on vernalization. Some of the material was subjected to various low temperature treatments during germination, but the phenomenon under consideration in this note did not appear to be associated in any way with these treatments. The plants were put out in the field in November 1941, and by the end of February 1942 most of them had reached the stage of development just prior to seed stalk formation. From this stage until the onset of winter, however, they made very little progress. During March most of the plants produced large numbers of lateral buds. In August growth was resumed, and early in September it was noticed that some of the developing flower stalks were flattened in form. During the next few weeks it became obvious that almost all the plants were more or less abnormal, the abnormality ranging from plants in which the stems were quite cylindrical but with an unusually large amount of branching, through plants with strap-shaped main stems, to plants in which the main stem was short, extremely flattened, and fan-shaped, as shown in the accompanying photographs (Plate 3). It is considered likely that the malformations were due to traumatic influence arising from injury to the growing points caused by aphids (*Brevicoryne brassicae*) which infested the plants during the early stages of growth. All plants, of all types, flowered and set seed freely, the yield from the plot being equivalent to 263 lb. per acre, compared with the average yield of seed of about 300 lb. per acre.

* An officer of the Division of Plant Industry.

The Pathogenicity of Single Spore Isolates of *Ophiobolus graminis* under Field Conditions.

By N. H. White, M.Sc., and G. A. McIntyre, B.Sc., Dip.Ed.†*

Summary.

The results of this experiment indicate that under field conditions (1) variations in pathogenicity of the eight isolates of *O. graminis* are significantly different for a particular medium, (2) these relative differences between isolates are not the same for different media, and (3) the effectiveness of the inoculum varies with site conditions.

This is an account of a preliminary experiment to test under field conditions the pathogenicity of eight isolates of *Ophiobolus graminis* derived from eight ascospores in a single ascus. There appears to be no possibility of repeating this experiment, but the writers feel that the results obtained are of sufficient value to be reported.

Sites were selected in a field at Canberra which two years prior to the experiment carried a crop of wheat affected by take-all, but lay fallow the year before the experiment, and was then prepared for sowing.

The isolates of the fungus were introduced into the soil in three types of inoculum, (*a*) straw, (*b*) oat-barley, and (*c*) soil, so that the effect of media on the pathogenicity of the isolates might also be observed. The inoculum was prepared by growing each of the eight isolates on three types of media for eight weeks at room temperature. The straw medium was prepared by autoclaving chaffed wheat straw with enough water to thoroughly moisten the straw without excess water. The oat-barley medium was the same as that generally used in preparing *O. graminis* inoculum. The soil medium was prepared in the manner described elsewhere.‡ the soil being obtained from the field in which the experiment was conducted.

Two adjacent sites each measuring 56 ft. x 8 ft. 6 in. were selected; one (*A*) was situated on light-coloured sandy loam, and the other (*B*) on a patch of dark-coloured sandy loam. In each of these, drills 8 ft. 6 in. long and 1 foot apart were opened up to a depth of 2½ inches. A standard measure of inoculum was placed in the bottom of each drill and 1 inch of soil placed on top of the inoculum so that the seeds were not in contact with it. Seeds were sown spaced at 2 inches apart with 50 seeds in each row, and then the drill was filled with the remaining soil. A treatment row alternated with a guard row, each block containing 27 rows in all. The treatments were randomized.

The number of seedling plants in each treatment row was noted and the percentage number of diseased plants determined at maturity. The diseased plants included those that were killed in the seedling stage, and dead and white-head plants at maturity. The rows giving the highest percentages of diseased plants also had the greatest number of plants showing seedling blight symptoms. None of the plants in the guard rows showed any disease symptoms. The percentages of diseased plants in the treatment rows are shown in Table 1.

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‡ White, N. H. (1942).—The genetics of *Ophiobolus graminis* Sacc. 1. Heritable variations for culture, colour, and pathogenicity, *J. Coun. Sci. Ind. Res.* (Aust.), 15: 118-124.

TABLE 1.—PERCENTAGE NUMBER OF DISEASED PLANTS IN EACH TREATMENT.

Site.	Medium.	Isolates.								Check.
		1	2	3	4	5	6	7	8	
A. Light coloured sandy loam	Straw ..	10	41	74	62	89	0	66	67	0
	Oat–barley ..	0	0	4	76	3	0	85	6	0
	Soil ..	0	2	48	2	0	0	0	10	0
B. Dark coloured sandy loam	Straw ..	0	41	80	4	4	0	0	66	0
	Oat–barley ..	0	0	0	71	0	0	29	0	0
	Soil ..	0	0	4	0	0	0	0	3	0

A statistical analysis was made of the results. In this analysis, check and isolate 6 were omitted because the evidence was consistent that the plants were not affected by the treatment, and hence their variances of zero could not be pooled with other data. The analysis on the log $(1 + x)$ transformed values for the seven isolates, shown in Table 2, indicates that differences in site and in the isolate-media complexes are highly significant. The isolates are significantly different within each medium, and the interaction of isolate and medium is also highly significant suggesting that the relative pathogenicity of isolates grown on straw, oat-barley, and soil media varies from isolate to isolate. In other words, although the eight isolates significantly differ in their pathogenicity, reference should be made only to the pathogenicity of an isolate or strain grown on a particular medium.

TABLE 2.—ANALYSIS OF VARIANCE.*

Source.	D.F.	Sum of Square.	Mean Square.	F.	Significance.
Blocks	1	2·4820	2·4820	17·56	P<·001
Isolate	6	4·6207	·7701	5·45	P<·01
Medium	2	7·0300	3·5150	24·88	P< 001
Interaction	12	8·4480	·7040	4·98	P<·001
Error	20	2·8251	·1413	..	..

The cultures on each medium were grown in at least five separate flasks and were bulked before application to the soil. On theoretical grounds this technique would be improved by pooling the inoculum of a strain grown on a particular medium into at least two separate lots, thereby doubling the treatments. The doubled number of treatments would be randomized within blocks. If the mean square between replicates were significantly less than the mean square between separate lots of inoculum, then the latter would be the appropriate error term for the comparison of strain-media complexes.

* By combining isolate, medium and interaction, the mean square for isolate-media complexes is 1.0494 significant at the .001 level. Similarly by combining interaction and isolate the mean square for isolate on the same medium is .7260 significant at the .001 level.

Smoke Curing of Fish.

Note on Some Results Obtained in the Experimental Kiln.

By E. W. Hicks, B.A., B.Sc., A.A.C.I., and M. C. Taylor, M.Sc.**

The experimental kiln built for this work has already been described in this *Journal* (**14**: 308, 1941).

A number of experimental runs with mullet (*Mugil dobula* Gunther) and Australian salmon (*Arripis trutta*) have been carried out. In these tests the wet and dry bulb temperatures of the air of the kiln have been recorded, and in the later runs fish temperatures were also measured by means of thermocouples.

Typical temperature-time curves for the two species studied are shown in Figs. 1 and 2.

The mean air velocity over the fish was 1·2 ft./sec. (approx.), so that the equilibrium temperature of a completely wet fish surface would be expected to be slightly above the wet bulb temperature. The curves for Australian salmon show fish temperatures moving roughly parallel to and slightly above the wet bulb temperature over practically the whole period, though there was an indication of a definite rise in fish temperature during the last half hour of the process. In runs with higher dry bulb temperatures this rise in fish temperature towards the end of the process was more clearly shown. This would suggest that the measurement of wet bulb temperature of the air of the kiln might be at least as useful to a kiln operator as that of the dry bulb temperature.

Australian salmon is relatively easily spoiled during smoke curing; if the fish temperatures are allowed to rise too high a milky exudate appears on the cut surfaces. Our experiments indicate that under the conditions in the experimental kiln the upper limit for wet bulb temperature is close to 26°C. (78·8°F.) for dry bulb temperatures ranging from 30°C. (86°F.) to 45°C. (113°F.). It cannot be asserted that a wet bulb temperature of 26°C. (78·8°F.) can be taken as a specification for the upper limit for safety for Australian salmon under all smoking conditions; in kilns without forced air circulation the limit may well be a little lower, particularly in warm humid weather. Nevertheless this figure should provide a useful approximation.

The graphs for mullet show a much greater divergence between fish temperature and wet bulb temperature than was observed in the case of Australian salmon. In the run represented in the curves, some of the fillets were deliberately left in the kiln rather more than an hour after they were judged ready to remove, in order to follow the changes in fish temperature and check the reality of the upward trend towards the end of the process. The differences in behaviour between mullet and Australian salmon may not be due entirely to differences in water relations of the tissues, because the temperatures used with mullet were higher than could be used with salmon.

It is quite evident that temperatures well above those that would cause spoilage in salmon may be safely used with mullet. Specification of the limit by means of wet bulb temperature may be less satisfactory

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for mullet than for salmon but it appears that, in the experimental kiln, wet bulb temperatures of at least 36°C. (96·8°F.) with dry bulb temperatures ranging from 45 to 50°C. (113 to 122°F.) may be used without spoiling the fish.

The mean weight losses during smoking in the runs represented in Figs. 1 and 2 were—

Australian salmon—10·7 per cent.

Mullet—21·0 per cent. in fillets left in kiln for 4½ hours.
17·2 per cent. in fillets removed after 3¼ hours.

It is likely that the differences in weight losses are due largely to the fact that mullet fillets have a greater surface to volume ratio than salmon. In each case the quality of the final product was good.

We wish to thank Mr. Reuben Allen of the Division of Food Preservation for the preparation of the fillets and assistance in carrying out the tests, and Mr. E. J. Ferguson Wood of the Division of Fisheries for arranging supplies of fish and for valuable advice and criticism.

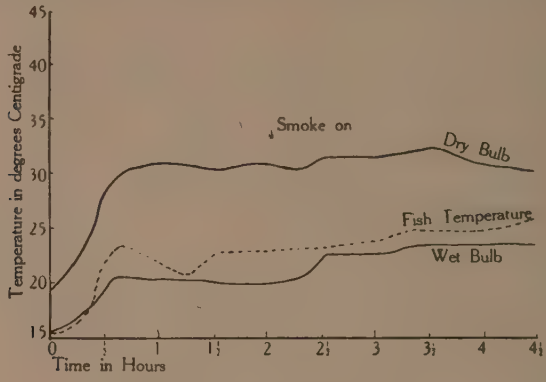

FIG. 1.—Australian Salmon.

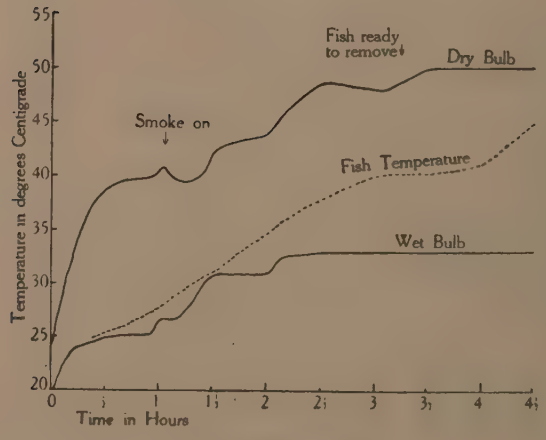

FIG. 2.—Mullet.

A New Method for Tomato and Cucumber Seed Extraction.

*By E. M. Hutton, B.Ag.Sc., M.Sc.**

Summary.

1. A new method has been discovered for the extraction of tomato and cucumber seed. It is designated as the acid extraction method and depends on the rapid dispersion of the colloidal seed sacs by mineral acids. This dispersion is at its optimum when the pH is reduced to 1·2 in both tomatoes and cucumbers.

2. Both hydrochloric and sulphuric acids are equally effective for acid extraction. With hydrochloric acid, the optimal addition for tomatoes, irrespective of variety, is 100 ml. per 25 lb. pulp and for cucumbers 125 ml. per 25 lb. of pulp. With sulphuric acid, one-third of these amounts suitably diluted with water is needed to produce the same result, so that it is a cheaper, although a more difficult acid to use.

3. Washing the seed can take place 15-30 minutes after the acid addition depending on how well the acid has been incorporated into the pulp. There is no reason why acid extraction cannot be made continuous with effective mechanical agitation.

4. Commercially, acid extraction has been a success with tomato seed. Cucumber seed extraction by this method presents washing difficulties which need to be overcome.

5. Germination of acid-extracted seed is as high as that of seed extracted by fermentation, but is more regular and even than that of seed extracted by fermentation.

6. It is possible that acid extraction may prove to be a reliable means of reducing seed-borne pathogens of tomato seed.

7. The cost of acid extraction is more than offset by its convenience and saving of time. It is possible that seed yields may be improved by this prcoess so that its cost would be further offset.

1. Introduction.

The usual fermentation method for the extraction of tomato and cucumber seed is well known. In the United States of America the tendency has been to develop quick methods which eliminate the time-consuming fermentation process. Quick methods, if relatively inexpensive, are highly desirable, as they not only save time, but also labour and the provision of extensive facilities for fermentation. Further, the seed extracted without fermentation is generally of better quality. Recently at Canberra, it has been discovered that the addition of commercial mineral acids to freshly prepared tomato or cucumber pulp results in a rapid dispersion of the colloidal sac surrounding the seed, so that the seed can be washed within a short time of the addition of acid.

2. The Acid Extraction Method for Tomato Seed.

(i) *Preliminary Laboratory Trials.*

Fruit of the Vetomold variety was picked at three stages of ripeness designated as Just Coloured, Ripe, and Over-ripe. Plate 4 shows these three stages. Table 1 lists the various treatments, each of which involved 5 lb. of well pulped tomatoes and the addition of commercial hydrochloric acid, except in the fermented controls.

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TABLE 1.—THE TREATMENTS AND THEIR EFFECT ON THE pH OF THE PULP AND THE QUALITY OF THE RESULTANT SEED.

Treatment Number.	Stage of Ripeness.	Amount HCl in ml. added per 5-lb. Pulp.	Time in Hours between Addition of Acid and Washing.	pH Just Prior to Washing.	Type of Seed Sample.	Germination Percentage of Seed Sample after 7 Days.	Germination Percentage of Seed Sample after 14 Days.
1	Just coloured	12·5	½	2·5	Poor	92	99
2	,,	,,	2	2·2	,,	97	99
3	,,	,,	8	2·2	Good	95	99
4	,,	25	½	1·2	Poor	96	97
5	,,	,,	2	1·0	Fair	98	99
6	,,	,,	8	1·3	Good	98	98
7	,,	50	½	·9	Fair	97	98
8	,,	,,	2	·9	Good	97	99
9	,,	,,	8	·9	,,	95	96
10	Ripe	12·5	½	2·5	Poor	95	98
11	,,	,,	2	2·2	Fair	98	99
12	,,	,,	8	2·5	Good	95	96
13	,,	25	½	1·2	Fair	98	100
14	,,	,,	2	1·1	Good	95	97
15	,,	,,	8	1·0	,,	98	99
16	,,	50	½	·9	,,	87	97
17	,,	,,	2	·9	,,	98	99
18	,,	,,	8	·9	,,	96	98
19	Over-ripe	12·5	½	2·5	Fair	98	98
20	,,	,,	2	2·2	,,	97	99
21	,,	,,	8	2·2	Good	98	98
22	,,	25	½	1·3	Fair	95	96
23	,,	,,	2	1·2	Good	98	98
24	,,	,,	8	1·1	,,	98	99
25	,,	50	½	·9	,,	96	97
26	,,	,,	2	·9	,,	98	99
27	,,	,,	8	·9	,,	94	97
28	Just coloured	Nil	Fermented 24 hrs.	3·9	Fair	60	80*
29	Ripe	,,	,,	4·1	,,	59	74*
30	Over-ripe	,,	,,	4·0	,,	56	73*

* Total germination after 3 weeks:—98 per cent., 95 per cent., and 97 per cent., respectively.

It can be seen from Table 1 that acid extraction is capable of producing seed of equal or better quality than that obtained by fermentation. Further, ripe fruit seems necessary for best results with acid extraction, although good seed can be obtained from just coloured tomatoes, if the time of contact or the amount of acid added is increased. For ripe and over-ripe fruit, the optimum pH for acid extraction of the seed appears to be close to 1·2, and this is obtained by adding hydrochloric acid at the rate of 25 ml. per 5 lb. of pulp. A period of ½ to 2 hours between the addition of the acid and washing the seed seems sufficient from the results in Table 1.

These treatments were carried out during hot weather so that the controls fermented rapidly and needed only 24 hours' fermentation for optimal results. The pH of the fresh tomato pulp, irrespective of the stages of ripeness cited, varied between 3·8 and 4·0. Controls fermented for 24 hours and 48 hours showed no significant reduction in pH, so that it can be inferred that dispersion of the gelatinous seed sacs during fermentation results from microbiological action and not from an increase in the hydrogen-ion concentration.

The seed samples from the acid treatments were in general a lighter and more attractive colour than those from the fermented controls. Table 1 shows that after a week a uniformly high germination resulted in the acid-extracted seed, whereas the seed from the fermented controls took three weeks to give as good a germination. The rates of growth of the seedlings from both the acid and fermentation treatments were similar.

A special trial was made to find what tolerance tomato seed has to hydrochloric acid. Acid was added at the rate of 50 ml. per 5 lb. of pulp and the seed was washed 72 hours after the addition of the acid. Samples of seed from this trial although discoloured gave 98 per cent. germination after a week, and the rate of development of the seedlings was more rapid than ordinary acid-extracted controls.

(ii) *Small-scale Commercial Trials.*

In Table 2 are given the results from small commercial trials of both the acid and fermentation methods of seed extraction. Each treatment involved four 25-lb. cases of Vetomold tomatoes. With the exception of one treatment, a mixed sample of ripe and over-ripe fruit, picked without any special selection, was used throughout. The acid extraction treatments used, followed as a result of the findings of the preliminary laboratory trials.

TABLE 2.—GIVING THE TREATMENTS USED IN THE SMALL-SCALE COMMERCIAL TRIALS AND THE RESULTS IN TERMS OF TYPE AND YIELD OF SEED.

Treatment Number.	Amount Commercial Hydrochloric Acid in ml. added per 25-lb. Pulp.	Time When Seed Washed Out.	pH Just Prior to Washing.	Seed Yield in Grammes per 25-lb. Case.	Type of Sample.
1	60	Soon as acid stirred in	2·0	64	Poor
2	60	After 1 hr. ..	2·3	78	Fair
3	100	Soon as acid stirred in	1·2	76	„
4	100	After 1 hr. ..	1·2	72	Good
5	120	Soon as acid stirred in	1·0	71	„
6	120	After 1 hr. ..	1·0	70	„
7	Nil	Control fermented 24 hrs. and washed	4·0	78	Fair
8	„	„ „	3·8	64	„
9	„	„ „	3·9	76	„
10	„*	Soon as fruit pulped	4·1	111†	Poor

* Very ripe, almost rotten, tomatoes used for this treatment.

† The extra weight is due to a high percentage of dried pulp which adhered to the seed.

Treatment No. 10 in Table 2 demonstrates that it is not possible to wash seeds by ordinary methods from rotten tomatoes which have fermented to some extent on the bushes. It appears from Table 2 that commercial hydrochloric acid added at the rate of 60 ml. per 25 lb. of pulp is near the minimal effective concentration, but will give results comparable to those obtained by ordinary fermentation, if the acid is well stirred in and the seed thoroughly washed an hour after the acid addition. Acid added at the rate of 100 ml. per 25 lb. of pulp reduces the pH to 1·2, and with a contact period of ½ hour to 1 hour before washing, appears to be the optimal treatment for commercial usage. The use of acid concentrations greater than 100 ml. per 25 lb. of pulp does not seem to be justified.

In Table 2 the results do not indicate any significant differences in seed yields between the acid extraction and fermentation methods. As found previously, the seed from the acid treatments was an attractive light buff colour, and that from the fermented controls was darker, although a good commercial sample.

(iii) *The Effect of Variety.*

Five-pound lots of pulp of a number of tomato varieties were each treated with hydrochloric acid at the rate of 100 ml. per 25 lb. of pulp and the seed washed after one hour. The varieties tested were Vetomold, Spark's Earliana, Beefsteak, Matchless, Marglobe, Burwood Prize, Potentate, Bonny Best, Earliwinner, Devlin's Choice, Recruit, Chalk's Early Jewel, Break o' Day, Red Marhio, Ponderosa, Sunnybrook Earliana, Golden Queen, Tatura Dwarf Globe, and San Marzana. The seed was washed with equal ease from all varieties and the seed samples were uniformly good. It appears that the acid extraction method works equally well with all varieties.

(iv) *The Effect of the Acid Extraction Method on Seed-borne Micro-organisms.*

That the acid acts as a sterilizing agent is shown by the clean mould-free germinations obtained in acid-extracted seed compared with the relatively mouldy germinations obtained in the seed from fermented controls. It was thought that acid extraction might have a depressing effect on the bacterial canker organism. Experiments by Mr. N. H. White, of the Pathology Section, Division of Plant Industry, demonstrated that the bacterial canker organism (*Aplanobacter michiganense*) will grow after being held for 10 minutes in a solution at a pH as low as 1·1. Below pH 1·1 it is killed, so that concentrations of acid greater than that required for optimal seed extraction would need to be used to ensure surface killing of the bacteria during extraction. It is sometimes said that the fermentation method of extraction will kill bacterial canker organisms on the seed. If this is so it is an effect unconnected with a lowering of the pH.

(v) *The Use of Sulphuric Acid for Acid Extraction.*

The other common mineral acid, sulphuric, was tried on a number of samples and proved as efficient as hydrochloric acid when used at similar concentrations. As sulphuric acid is more difficult to handle than hydrochloric, it is not recommended for general use by people not fully aware of its properties. Concentrated sulphuric acid as

bought, would cause charring and damage to seeds if added to the pulp without dilution. It is diluted by slowly and carefully pouring the acid into water and allowing the resultant solution to cool.

To make a sulphuric acid solution equivalent to commercial hydrochloric acid, sulphuric acid needs to be diluted with two and a third its volume of water. To make 100 ml. of sulphuric acid solution sufficient to treat 25 lb. of tomato pulp with the optimum concentration of acid, 30 ml. of the acid are carefully poured into 70 ml. of water and cooled.

On a volume basis there is little difference in price between hydrochloric and sulphuric acid, but as sulphuric acid is used at only one-third of the rate of hydrochloric acid volumetrically, sulphuric acid is cheaper to use.

3. The Acid Extraction Method for Cucumber Seed.

Early Fortune cucumbers crushed whole, and also pulp obtained by cutting cucumbers in halves lengthwise and scraping the seeds and adhering material from the skins, were given a number of treatments based on the results of the tomato seed extraction experiments. These treatments and the results produced by them are given in Table 3.

Table 3.—Acid and Fermentation Methods of Seed Extraction Compared in the Cucumber Variety, Early Fortune.

Treatment Number.	Type and Amount of Material Treated.	Amount Commercial HCl in ml. added per 5-lb. Material Treated.	pH at Washing, 15 Minutes after the Acid Addition.	Type of Seed Sample Produced.
1	10 lb. crushed cucumbers	12½	1·6	Poor
2	„ „ „	25	1·2	Good
3	„ „ „	50	·9	„
4	5 lb. scraped-out pulp	12½	3·3	Poor
5	„ „ „	25	1·7	Fair
6	„ „ „	50	·9	Good
7	10 lb. crushed cucumbers	Fermented control	4·1*	„
8	5 lb. scraped-out pulp	„ „	4·2*	„

* pH at washing after 48 hours' fermentation.

The trials were conducted during hot weather, and it was found that the controls needed 48 hours' fermentation under these conditions to give a satisfactory seed extraction. As with the fermented tomato controls, the cucumber controls showed little change of pH as a result of fermentation, so that dispersion of the gelatinous seed sacs in cucumbers by this method appears also to be a result of microbiological activity. It is apparent from Table 3 that a pH in the vicinity of 1·2 is necessary for satisfactory seed extraction with cucumbers. This was also the case with tomato seed extraction. With cucumbers broken in a coke crusher, the addition of hydrochloric acid at the rate of 25 ml. per 5 lb. of pulp reduced the pH to 1·2 and produced a good seed sample. When the pulp was scraped out the addition of acid at the rate of 35 ml. per 5 lb. of pulp is needed to reduce the pH to 1·2 so that satisfactory seed extraction may be obtained. All the seed samples from the treatments gave a good germination.

A few semi-commercial trials proved that the findings of Table 3 were correct. They demonstrated, however, that when whole cucumbers were crushed and then acid-treated, the skins, flesh, and seed sink together during washing and are difficult to separate. This difficulty did not appear at all with tomatoes. It was found that the coke crusher helped to avoid this difficulty in cucumbers, as it broke them into relatively large pieces which could be sieved out from the seeds during washing. If the cucumbers are mashed up thoroughly, it is almost impossible to separate seeds, flesh, and skin during washing after acid treatment.

It was difficult to obtain sufficient cucumbers for extensive trials, but enough data have been accumulated to demonstrate that acid extraction has distinct promise.

4. Commercial Usage of the Acid Extraction Process for Tomato and Cucumber Seed.

The acid extraction method has been successful on a commercial scale with tomato seed and has been reported on favorably by several people. Extraction of cucumber seed by the method has not been tried as extensively, and where it has been tried the washing difficulties cited previously have been encountered.

The advantages of acid extraction over fermentation so far reported and observed with tomatoes are as follows:—

(1) The saving in time. Fruit can be picked, and the seed extracted and dried the same day. As a result inclement weather can be avoided. With fermentation for relatively long periods of one to three days, adverse weather may develop before drying can be started.

(2) It is not necessary to leave the fruit on the bushes until overripe. All the ripe fruit can be picked at once and treated. Due to this fact, and the rapidity of the method, one picking serves where several pickings had to be made with fermentation.

(3) The number of barrels or containers for pulp is reduced to capacity necessary to hold half-hour's crushing instead of perhaps one day's crushing. Where mechanical crushers are used, the lack of containers can create a distinct bottleneck in harvesting operations. A small mechanical crusher will crush ten 40-gallon barrels per hour. If the crop were to be fermented, 80 barrels would be needed to hold a day's crushing. With acid extraction only 10-12 barrels are needed to handle the same amount of pulp.

(4) Under conditions of low and high temperatures, fermentation difficulties are obviated. In cold weather fermentation has to be prolonged, so that the seed sample tends to be poor. In hot climates very rapid fermentation and putrefaction of the pulp results in discoloured seed of low vitality. Acid extraction overcomes these difficulties as it eliminates fermentation.

(5) Higher seed yields. This has not been proved conclusively, but all reports suggest that the easier and cleaner separation obtained by acid extraction appears to give a better seed yield per ton of fruit compared with fermentation.

(6) Rapid treatment of large quantities of fruit by mechanical means is possible with acid extraction. With mechanical mixing of the acid through the pulp the process could be made practically continuous.

Those who have used the acid extraction method on a commercial scale with tomato seed agree that the addition of 100 ml. or 3 fl. oz. of hydrochloric acid per 25 lb. of pulp cited previously is the best. This is equivalent to the use of approximately 2 gallons of commercial hydrochloric acid per ton of tomatoes. With hydrochloric acid at 3s. 4d. per gallon the cost would be 6s. 8d. per ton of fruit. So far, commercial acid extraction has been carried out with hydrochloric acid, and it has been agreed that the cost of the acid is more than offset by the advantages of the method over fermentation.

Where tomato seed extraction is conducted on a large scale, it would pay to investigate the possibility of using commercial sulphuric acid. This would be used at the rate of two-thirds to 1 gallon per ton, and its use should at least halve the cost of acid extraction.

Whether acid extraction is used on a large or small scale with tomatoes, success depends on efficient pulping and the thorough incorporation of the acid through the pulp by stirring. In general, a period of half to one hour before washing after the addition of the acid is necessary depending on the efficiency of the stirring. Mr. Eric Rumsey, of Seed Growers Co-operative Limited, New South Wales, found in commercial trials of the new method, that the dilution with 2 gallons of water of each 12 fl. oz. of hydrochloric acid needed per 100 lb. of pulp reduced the time before washing to as low as 15 minutes.

Galvanized iron containers coated inside with quick drying bituminous paint or wooden barrels are the best treatment vessels. Freshly extracted seed should be well drained and then spread on hessian to dry. If dried in contact with metal, the seed is apt to become discoloured under slow drying conditions due to traces of acid present on the seed.

5. Acknowledgments.

The co-operation of Mr. Eric Rumsey, of Seed Growers Co-operative Limited, New South Wales, and Mr. W. R. Watkins, Manager of Leeton Experiment Farm, is gratefully acknowledged for providing details of their commercial trials with the new method. Mr. G. Rasmussen, of the Division of Plant Industry, supplied the tomatoes and cucumbers used in the trials and helped considerably in the experiments.

The Production of Swede Turnip Seed at Canberra, A.C.T.

By S. G. Gray, B.Sc.Agr. and L. Sharp**

Summary.

At the Dickson Experiment Station, Canberra, A.C.T., a yield of 3,243 lb. of good quality Purple Top swede turnip seed was produced from 6·81 acres in an experiment in seed to seed production during April to December, 1942.

In a subsidiary experiment on a 2-acre block it was shown that thinning to 6 in. or 12 in. between plants had no significant effect on the yield and little effect on average seed weight.

A crop of Purple Top swede turnip seed was produced at the Council's experiment station at Dickson, Canberra, A.C.T., in the 1942 season. The total area of 6·81 acres comprised three blocks containing 2·04, 1·70, and 3·07 acres respectively. A thinning experiment was conducted on one block.

1. Soil Preparation and Seeding.

The soil, a red loam, was cultivated with a mould-board plough and maintained as a well-worked fallow until sowing time. Immediately before sowing it was cultivated with a spring-tine cultivator, pulverized and consolidated with a cultipacker, and then harrowed across the packer ridges with diamond harrows. The areas were given a dressing of 121 lb. per acre of 22 per cent. superphosphate and were again harrowed. One block, which was somewhat rougher than the others, received an additional packing and harrowing.

Seeding was done in a dry seed-bed from 17th to 22nd April, 1942. Seed was sown with a Planet Junior single row hand pusher seed drill at a depth of ½ inch in rows 3 feet apart, at the rate of 2 lb. per acre. Sowing in rows 3 feet apart was adopted to allow intercultivation with available machinery. The time taken by one man to seed the whole area of 6·81 acres was 2½ days.

Two cultivations with a Planet Junior motor cultivator were given, one in mid-May and the other in mid-July.

2. Thinning Experiment.

It was decided to do an experiment on the 2·04-acre block to determine the effects of thinning on yield and quality of seed. Three treatments were tested, namely (*a*) unthinned, (*b*) thinned to about 6 inches between plants, and (*c*) thinned to about 12 inches between plants. The plots were arranged in randomized blocks, with five replications. Thinning was done when the plants were about 6 inches high.

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* An officer of the Division of Plant Industry.

3. Harvesting.

Harvesting took place from 18th to 23rd December. Each of the three blocks was harvested by a different method. The first one, containing 1·70 acres, was cut by hand, the stems being slashed and tied into sheaves. The harvesting of this block took approximately two days for two men and six girls. The next block, which was the one on which the thinning experiment was conducted, was cut with a mower, one row at a time, and one row from each plot was handled separately to provide data on the effects of thinning. The 2·04 acres in this block took the same team a little over one day to cut. The final block, of 3·07 acres, was cut with a reaper and binder. Owing to the weather at the time, work with the binder had to cease at 10 a.m. as the pods were beginning to shatter, and the remainder of the block was cut in the moonlight the same night, when the crop had toughened up.

4. Threshing.

As all sheaves contained a proportion of green material, they were windrowed on a level patch of hard ground to complete drying.

The sheaves were then laid in a single layer on a large tarpaulin, with heads overlapping butts, and threshed by running the tractor and cultipacker over them a few times. The straw, still in sheaf form, was shaken and tossed aside with pitch-forks. The threshed material was then readily bundled in the tarpaulin for removal to the winnower. It was then put through an ordinary Federal winnower to remove all larger pieces, and cleaning was completed by passing the material through a Bodington seed cleaner. It was necessary to put the material through twice in order to obtain clean seed.

5. Rainfall Data.

The rainfall for the season is shown in Table 1. The total rainfall during the life of the crop, that is from 17th April to 23rd December, was 2,094 points.

Table 1.—Rainfall at Dickson, A.C.T., 1942.

Month.	Points.
January	26
February	194
March	130
April	9
May	528
June	332
July	186
August	202
September	228
October	175
November	383
December	54
Total	2447

6. Results.

(i) *General.*

The total yield of seed from 6·81 acres was 3,243 lb. or 476 lb. per acre. This yield is considered very satisfactory. Samples of the seed gave an average weight of 3·34 grammes per 1,000 seeds, or approximately 136,000 seeds per pound as compared with the usual 154,000. Germination tests conducted several weeks after harvesting gave 97 per cent. germination in four days.

(ii) *Thinning Experiment.*

Data from the thinning experiment are summarized in Table 2. Plant counts were made on random samples within each plot immediately before harvest, and the results calculated as number of plants per acre. One row from each plot was cut and threshed separately. An analysis of variance on the yield of seed from these rows indicated that differences between treatments were not significant at the 5 per cent. level.

Weight per seed was estimated from a sample obtained from each plot, and analysis of variance showed that thinning to 12 inches gave a barely significant increase in weight per seed, but there was no significant difference in this character between unthinned material and material thinned to 6 inches.

Plant height measurements indicated that unthinned plants were slightly taller than thinned. The most obvious effect of thinning, however, was in the amount of branching developed. The number of primary branches per plant was 4·92 in the unthinned material, 8·98 in material thinned to 6 inches, and 10·74 in material thinned to 12 inches. The differences are significant at the 1 per cent. level. The stems in the thinned plots were much thicker than those in the unthinned plots, thus making the unthinned material somewhat easier to harvest than the thinned.

It is interesting to note that despite the very large differences in number of plants per acre, the yields of seed obtained are so similar. It is evident that thinning to 6 inches or 12 inches has greatly affected the branching habit of the plants, but has not resulted in any significant alteration in yield of seed per acre. Thinning to 6 inches has had no effect, and thinning to 12 inches has had very little effect, on average seed weight.

Table 2.—Effects of Thinning on Seed Production.

Character.	Unthinned.	Thinned to 6 in.	Thinned to 12 in.	Standard Error.
Number of plants per acre in thousands	84·2	26·1	15·3	..
Yield per acre in lb.	610·4	539·1	549·9	32·1
Average seed weight in milligrammes	3·30	3·28	3·44	0·05
Primary branches per plant ..	4·92	8·98	10·74	0·33
Average plant height in inches ..	61·89	60·29	59·24	0·45

Two Promising Insecticides.

By G. A. H. Helson, M.Sc. and R. F. Powning, A.S.T.C., A.A.C.I.**

A recent study of the insect vectors of potato virus diseases by the Division of Economic Entomology has revealed two promising insecticides, one of which may be used instead of nicotine sulphate, which is mainly imported from overseas and is consequently difficult to get. This particular insecticide, "Paranaph," is by no means new, but has been forgotten for a considerable time. The other is a modification in which a coal tar distillate is substituted for one of the constituents of "Paranaph." Experiments with both these insecticides are still in progress, and a detailed account of the results will be published later. The object of this note is to assist those who may wish to test the materials for themselves.

As long ago as 1895, H. Cousins of Cambridge University patented an insecticide called "Paranaph" which consisted of an intimate mixture of soft soap, naphthalene, and kerosene. It was claimed to be of superior stability to the ordinary kerosene-soap emulsions, and was recommended for the control of various insects, particularly aphids, when used at the rate of 1½ per cent. Later it was used in the West Indies against fleas, ticks, scale insects, and aphids, but after 1914 its use gradually diminished.

Tests have shown that at 1½–2 per cent. it is an excellent contact insecticide for the control of cabbage aphis, *Brevicoryne brassicae* L., which is very difficult to kill with nicotine sulphate, and that it is not quite as effective as nicotine sulphate against other species of aphids. The tests have also shown that its great advantage over nicotine sulphate against cabbage aphis is its effectiveness at low temperatures—as low as 48°F.—thus controlling the aphis during the cooler months of the year and at times when nicotine sulphate is ineffective. It has the added advantage of being innocuous to the larvae of syrphid flies which prey upon the aphids. Its extreme wetting properties enable it to wet the insects on impact, and thoroughly to wet the plants sprayed. In comparison with a standard kerosene emulsion (1:8) a 2 per cent. "Paranaph" spray contains five times as much soap and one twenty-third of the amount of kerosene.

When an attempt was made to substitute for the kerosene a distillate of coal tar to yield a mixture made entirely from Australian materials, it was found that a certain spraying creosote with a boiling range 250°–350°C. could be used for this purpose. This oil had previously been found toxic and repellent to aphids but was injurious to plants. It was thought that the mixture "Creonaph" might combine the toxic repellent properties of the creosote with the wetting properties of the soft soap, and at the same time reduce the phytocidal effect of the creosote. In the field at Canberra, concentrations up to 2 per cent. had no injurious effect on the foliage of apricot, peach, swede turnip, silver beet, mustard, and roquette, and no effect on the fruit of apricot or peach. At 2 per cent. it discoloured the flowering heads of carrots,

* Officer of the Division of Economic Entomology.

but did not prevent the seed from setting. Potato and tomato foliage turned a dark-brown a day or so after spraying with 1½ per cent., and some damage to tomato flowers was produced. Its effects on all crops under different conditions, however, is not known, and at the present stage it should, therefore, be used with *extreme caution*.

When tested against various insects, it was found to be very effective against Rutherglen bug, *Nysius vinitor* Berg., and, at 2 per cent. concentration, gave a complete kill of the adults of this species. A field test with a single spray on the flowering heads of carrots immediately reduced the population to 20 per cent. and permitted the seed to set. The population remained at the 20 per cent. level for a fortnight without further spraying. Present indications are that the mixture provides a practical method of control for the insect, and further trials against this pest should be made. The same concentration was found to destroy the youngest stages of the green vegetable bug, *Nezara viridula* L.

"Paranaph" may be prepared as follows:—To 56 lb. of fresh soft soap add 2 gallons of water. Simmer over a fire with constant stirring until all lumps have disappeared and a perfectly uniform melt is obtained. Add 6 lb. of "whizzed" or flake naphthalene, and stir until dissolved. *Remove* from the fire and add 2 imperial gallons of kerosene. Stir until uniform. The finished product should be semi-solid and of uniform texture throughout. It readily mixes with water to give a milky emulsion. It is essential that a fresh soft soap that melts easily, and mixes with water, be used; otherwise it is difficult to obtain a uniform mixture with the kerosene.

The mixture should be used at the rate of 1½ to 2 gallons per 100 gallons of water, or three to four tablespoons to the gallon. Soft water is preferable to hard.

"Creonaph" is made in exactly the same way except that 2 gallons of spraying creosote, boiling range 250°–350°C., are substituted for the kerosene. Use at the same rate as "Paranaph."

NOTES.

Autumn School in Oceanography.

At the commencement of this year a course in comparative biochemistry was instituted at the University of Sydney's Department of Biochemistry, and it was thought advisable to endeavour to obtain for the students concerned an opportunity of studying a range of living material in its natural environment and to inform them of the activities of a research institution concerned with biological problems relating to animals other than those studied in medicine and veterinary science. The Council's Division of Fisheries was approached in the matter, and it was decided that a school in marine biology should be held at the Fisheries Division's Laboratory, at Cronulla, on behalf of the senior students of biochemistry. It was decided that the Zoology Department should be informed of the project, and this Department decided to give its senior students the opportunity of attending the school, the plans for which were then immediately developed.

The main objectives were simple in concept. Three introductory lectures were devoted to definitions and a general description of methods of technique. Following these lectures there was an exercise in actual routine planktological and hydrographical observations, the necessary sampling being carried out at two points in Port Hacking. The material collected in this exercise by the students was then analysed by them and the results developed in graphical form for interpretation. The net results of this work were then discussed in colloquium. Finally, a set of four lectures dealt with a general survey of some of the principal factors of planktological and hydrographical research, ending with an account of the use which is made of these oceanographical studies in the economic study and control of fisheries generally.

The school was attended by five students from the Department of Biochemistry, accompanied by two of the lecturing staff, and by ten students from the Department of Zoology, accompanied by three of the lecturing staff. In addition, one of the lecturing staff of the Department of Zoology at the University College of Armidale was present.

Despite minor difficulties it proved possible to carry this programme through almost as originally planned. The field exercise was not very successful because of some technical difficulties and of inclement weather. However, sufficient material was collected to permit of some interesting analyses being made and to allow of some discussion at the colloquium.

It is hoped that it will be possible to make this school, which was of an experimental nature to determine the possibilities, a regular annual feature, and that selected students from the universities of other States will be able to participate.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following publications of the Council have been issued:—

Bulletin No. 154.—"The Handling and Storage of Australian Oranges, Mandarins, and Grapefruit." Report of Investigations carried out under the direction of the Citrus Preservation Technical Committee from 1935 to 1941, and compiled by F. E. Huelin, B.Sc., Ph.D.

The investigations on which the Bulletin is based were carried out by officers of the Council, of the Departments of Agriculture in New South Wales, Victoria, and South Australia, and of the Waite Agricultural Research Institute, South Australia. Much of the cost involved was met from a special grant made by the Commonwealth Government.

Different varieties of oranges—Navels, Valencias, Joppas, &c., all of which behave differently in cool storage, have been studied. Amongst the findings the following are included—keeping quality is influenced by factors operating prior to picking, i.e., district, grove, tree, position of tree, irrigation and manuring. Storage spot in Navel oranges is reduced by Bordeaux sprays. Wastage is affected irregularly by date of picking. If rots predominate, the earlier picked fruit usually keeps better. If storage spot predominates, the reverse may be the case. Sweating generally but not always, reduces the development of storage spot; this effect may be modified by temperature of sweating, picking date, and the degree of wilting. In a large number of experiments storage spot and total wastage have generally been less after a long storage period at 50°F. than at lower temperatures. This conclusion would only be true for carefully handled fruit which was free from stem-end rot or other infections at picking. Wilting is increased by alkaline detergents and borax and considerably reduced by waxing, either by dipping in waxed emulsions or spraying with molten wax (hot fog process). A number of recommendations are made with reference to the export trade.

Bulletin No. 155.—"The Lubricating Effect of Thin Metallic Films and the Theory of the Action of Bearing Metals," by F. P. Bowden, Sc.D. (Cantab.), and D. Tabor, Ph.D. (Cantab.), A.R.C.S.

In this Bulletin the action of bearing metals is discussed. The friction of different metallic alloys is shown to be considerably less than that of any of the constituent metals, but the lowest friction of all is obtained with thin films of soft metal deposited on to a hard metallic substrate. Under certain conditions the coefficient of friction is lower than that observed for lubricated metals and is comparable to that of ice. If an alloy consists of a soft metal dispersed through a harder matrix, its frictional properties resemble very closely those of a hard surface (consisting of the matrix material) over which a thin film of the softer metal has been spread. These results are discussed in relation to the general theory of the action of bearing metals.

Bulletin No. 156.—"Standardized Plant Names. A List of Standard Common Names for the more Important Australian Grasses, other Pasture Plants, and Weeds," prepared by the Division of Plant Industry.

The work of compilation of these lists has been spread over a number of years as opportunity permitted. Many Australian organizations such as the State Departments of Agriculture, and Royal Societies, have been

consulted, and it is hoped that much of the present confusion in common names of grasses will disappear as a result. Two instances of this confusion are as follows:—The plant known botanically as *Echium plantagineum* is known as Salvation Jane in South Australia, whereas in the eastern States it is known as Paterson's Curse. Then again, the name "browntop" is almost universally applied in the southern States and in the seed trade to *Agrostis tenuis*, whereas in Queensland "browntop" is the common name of the tropical and sub-tropical plant *Eulalia fulva*. There would be little hope of securing acceptance of a completely different common name for either of these grasses. Accordingly, it is proposed to distinguish the species of *Agrostis* as "browntop bent" and *Eulalia fulva* as "silky browntop."

Bulletin No. 157.—"Studies in the Biology of Australian Mullet. 1. Account of the Fishery and Preliminary Statement of the Biology of *Mugil dobula* Gunther," by G. L. Kesteven, B.Sc.

This Bulletin gives an account of the mullet fishery of Australia and a preliminary statement of the life history of the sea mullet (*Mugil dobula*). This mullet spends the greater part of the year in the rivers and lakes of the coast, and a few months in moving along the coast in a spawning migration. It has been widely believed by fishermen and others that the slimy, dark, lake and river mullet are quite distinct from the clean, shining blue, sea fish, and not merely different phases of the one life history. However, river fish have been tagged and recovered later as sea fish. Investigations have shown that serious depletion of the mullet stocks is occurring. Fewer mullet were caught in 1936 than in 1915, though more men and many more boats were employed in 1936. The catch per man has greatly decreased and will continue to decrease unless the stocks are allowed to recover. Before the life history of the mullet was properly understood, it was impossible to plan a satisfactory scheme for controlling the fishery. The work described in the present Bulletin should form the basis for a plan to control the mullet fishery so that over-fishing will not occur, and when the stocks have recovered, the annual catch will increase.

Bulletin No. 158.—"The Recovery of Inter-block Information in Quasi-Factorial Designs with Incomplete Data. 1.—Square, Triple, and Cubic Lattices," by E. A. Cornish, M.Sc., B.Agr.Sc.

This is the first of a series of papers concerned with the recovery of information in quasi-factorial designs that have incomplete data. The paper describes an approximate method for dealing with square, triple, and cubic lattices and discusses the effect of the approximations on the estimation of the adjusted treatment effects and their errors and the analysis of variance.

Bulletin No. 159.—"Poisonous and Harmful Fishes," by G. P. Whitley, F.R.Z.S.

This Bulletin is a practical guide to the poisonous and harmful fishes likely to be encountered in Australia, New Guinea, and the islands of the South-west Pacific. Its aim is to enable members of the Forces and other persons in Australia and adjacent seas to recognize and avoid those fish that are poisonous if eaten, or those that are able to cause excruciating pain by stinging with their spines. The Bulletin is written in non-technical language, but a more detailed scientific report is being prepared for separate publication.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 160.—"The Outbreak of the Australian Plague Locust (*Chortoicetes terminifera* Walk.) in the Season 1939-40, with Special Reference to the Influence of Climatic Factors," by K. H. L. Key, M.Sc., Ph.D.

Bulletin No. 161.—"A Review of the Evidence Concerning Expansive Reaction between Aggregate and Cement in Concrete," by A. R. Alderman, M.Sc., Ph.D., F.G.S.

Bulletin No. 162.—"The Soil and Land-Use Survey of the Wakool Irrigation District, New South Wales," by Robert Smith, B.Sc. (Agric.), R. I. Herriot, B.Ag.Sc., and E. J. Johnston, B.Sc.Agr.

Bulletin No. 163.—"Transmission of Potato Virus Diseases. 1.—Field Experiment with Leaf Roll at Canberra, 1940-41," by J. G. Bald, M.Agr.Sc., Ph.D., and D. O. Norris, B.Sc. (Agric.). "2.—The Aphis Population of Potatoes at Canberra during 1940-41," by D. O. Norris, B.Sc. (Agric.), and J. G. Bald, M.Agr.Sc., Ph.D.

Bulletin No. 164.—"Studies in the Biology of the Skin and Fleece of Sheep. 1.—The Development and General Histology of the Follicle Group in the Skin of the Merino. 2.—The Use of the Tanned Sheepskin in the Study of Follicle Population Density. 3.—Notes on the Arrangement, Nomenclature and Variation of Skin Folds and Wrinkles in the Merino," by H. B. Carter, B.V.Sc.

Bulletin No. 165.—"Potato Virus: Mixtures of Strains and the Leaf Area and Yield of Infected Potatoes," by J. G. Bald, M.Agr.Sc., Ph.D.

Bulletin No. 166.—"Fertility in Sheep. An Experimental Study of Periodicity of Oestrus and Non-breeding Seasons in Australia," by R. B. Kelley, D.V.Sc., and H. E. B. Shaw, B.V.Sc.

Bulletin No. ?.—"A Survey, Census, and Statistical Study of the Horticultural Plantings on the Murrumbidgee Irrigation Areas, New South Wales," by A. Howard, M.Sc., A.A.C.I., and G. A. McIntyre, B.Sc.

Bulletin No. ?.—"The Entomological Control of St. John's Wort (*Hypericum perforatum* L.), with Particular Reference to the Insect Enemies of the Weed in Southern France," by F. Wilson.

Bulletin No. ?.—"Zebu-Cross Cattle in Northern Australia. An Ecological Experiment," by R. B. Kelley, D.V.Sc.

Industrial Chemistry Circular No. 2.—"Investigation of Low-Tin and Tin-Free Solders," by H. W. Worner, M.Sc., H. T. Greenaway, B.Met.E., and J. H. Buckley, B.Sc.

Industrial Chemistry Circular No. 3.—"Melting and Casting of Magnesium Alloys," by H. A. Stephens, B.Sc.

PLATE 1.

Insect Transmission and Host Plants of Virescence. (See page 85.)

Virescence : Flowers from diseased and healthy plants *Hypochaeris radicata* (above) *Antirrhinum* sp. (below).

C.3576/43.—6

PLATE 2.

(Fig. 1) Insect Transmission and Host Plants of Virescence. (See page 85.)

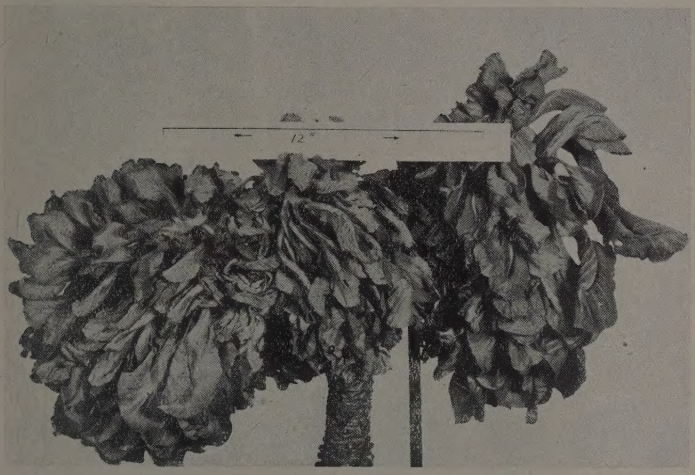
(Fig. 2) Strains of Spotted Wilt Virus and the Identity of Tomato Tip-Blight Virus with Spotted Wilt. (See page 91.)

FIG. 1.—Virescence: Flowers from diseased and healthy *Phlox Drummondi*.

FIG. 2.—Tomato, variety Kondine Red, 18 days after inoculation with necrotic strain of spotted wilt.

PLATE 3.

Fasciation in Cabbage. (See page 92.)



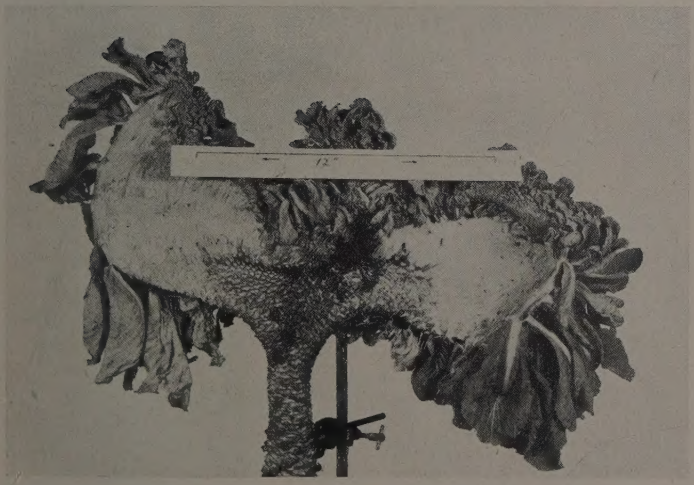
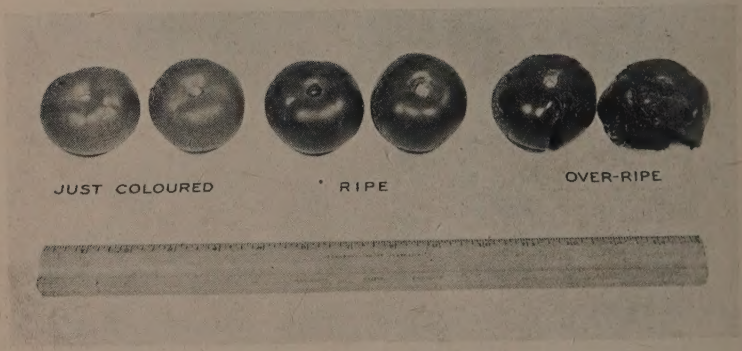


FIG. 1 (above).—Side view of fasciated cabbage plant.
FIG. 2 (below).—The same plant with leaves removed to show flattened stem.

[*Photos by R. S. B. Millett.*]

PLATE 4.

A New Method for Tomato and Cucumber Seed Extraction.
(See page 97.)



Vetomold tomatoes picked at three stages of ripeness.

H. E. Daw, Government Printer, Melbourne.

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